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Combined Sewer Overflow Toxic Pollutant Study

Jordan (Edward C.) Co., Inc., Portland, ME

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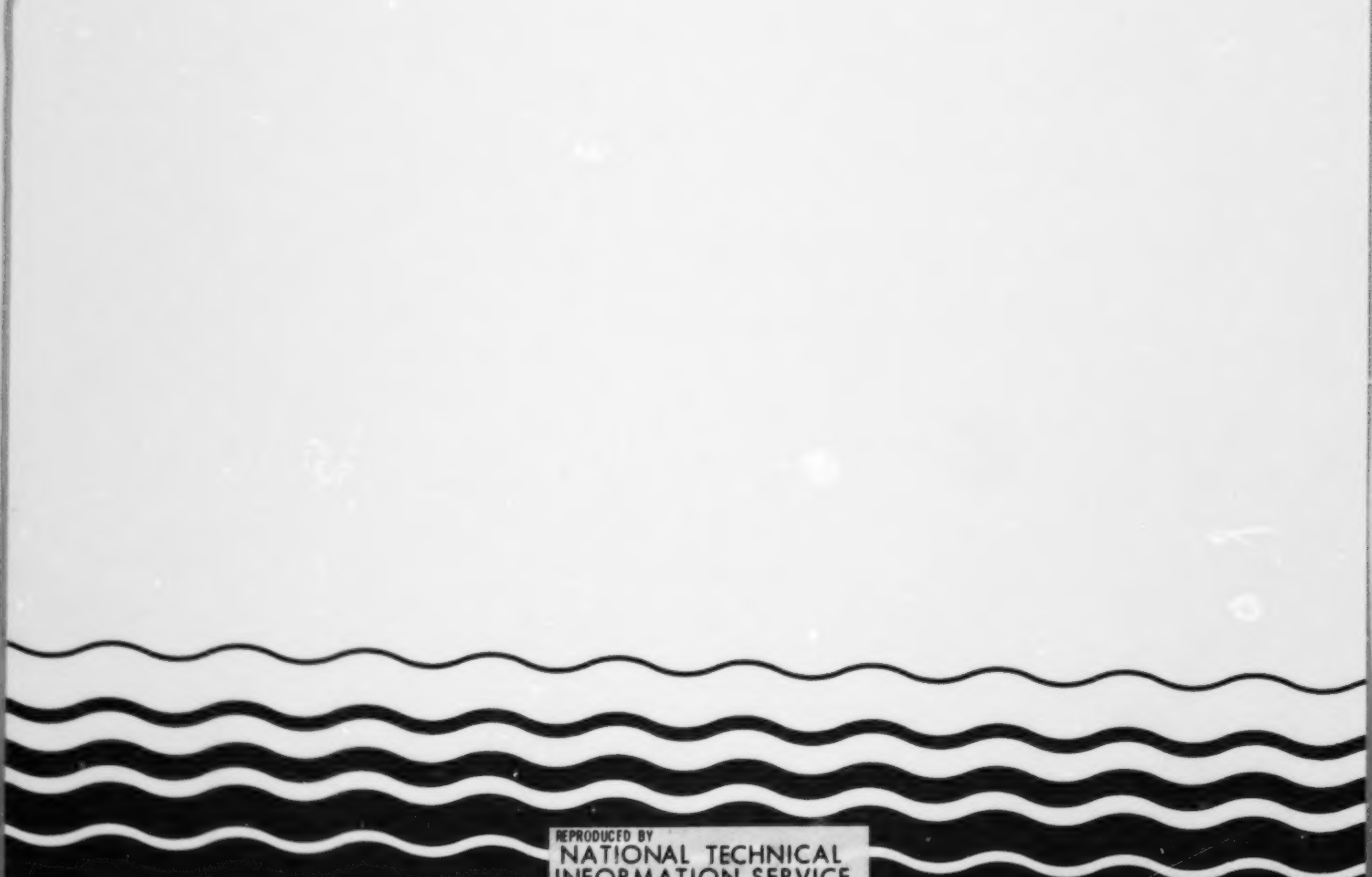

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The purpose of this study is to document the occurrence, concentration, mass, and source of priority toxic pollutants in combined sewer flows (CSF). CSF, combined sewer overflow, first flush flow, runoff, and precipitation samples were collected in eight drainage areas and analyzed for specified conventional and nonconventional pollutants and for priority toxic pollutants. Twenty-two storm events were sampled. Background dry weather flow, tap water, and sediment samples were also collected in the eight drainage areas and analyzed for the same pollutants that the wet weather samples were analyzed for.

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prepared by

E.C. Jordan Co.
562 Congress Street
Portland, Maine 04112

prepared for

U.S. Environmental Protection Agency
Effluent Guidelines Division

EPA Project Officer
Robert M. Southworth, P.E.

April 1984

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ABSTRACT

This project was initiated to document the occurrence, concentration, mass, and source of priority toxic pollutants in combined sewer overflows (CSOs).

Wet weather samples of CSO, combined sewer flow, first flush flows, runoff and precipitation were collected during 22 distinct storm events. These samples were collected from eight drainage areas in four cities (two drainage areas per city). In addition, background dry weather flow samples, tap water samples and sediment samples were collected in the eight drainage systems. All samples were analyzed for specified conventional and nonconventional pollutants and for 125 priority toxic pollutants.

The occurrence of pollutants in combined sewer overflows, the concentration of these pollutants, pollutant mass factors (pounds of pollutant per acre of drainage area per inch of rainfall), and projected CSO pollutant masses on a nationwide basis are presented. Results of an evaluation of the pollutant mass associated with the first flush phenomenon are also presented. Toxic pollutant masses attributable to runoff are quantified and a mass balance analysis of the combined sewer systems sampled is presented. The mass balance analysis included identification of sources of toxic pollutants and the discharge pathways of these pollutants. Factors affecting pollutants in combined sewer flows and CSOs are discussed.

This report was submitted in fulfillment of Contract No. 68-01-5772 by the E.C. Jordan Company under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period from October 1, 1981 to April 1, 1984. Work was completed as of April 1, 1984.

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LIST OF ABBREVIATIONS AND SYMBOLS

BOD5 - biochemical oxygen demand
CATAD - computer augmented treatment and disposal
CFS - cubic feet per second
cm - centimeter
COD - chemical oxygen demand
CS - combined sewer
CSF - combined sewer flow
CSO - combined sewer overflow
°C - degrees centrigrade
ct-cv - constant time-constant volume
Dup - duplicate
EPA - Environmental Protection Agency
GPD - gallons per day
msl - mean sea level
mgd - million gallons per day
mg/l - milligrams per liter
min - minutes
ml - milliliter
PAH - polynuclear aromatic hydrocarbons
POTW - publicly owned treatment works
QA/QC - quality assurance/quality control
SCSS - storm and combined sewer section
TCU - telemetry control unit
TOC - total organic carbon
TS - total solids
TTVO - total toxic volatile organics
TVS - total volatile solids
TSS - total suspended solids
VOC - volatile organic compounds
μmhos/cm - micromhos per centimeter

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SECTION 1

SUMMARY AND CONCLUSIONS

SUMMARY

Results from several previous studies conducted by the U.S. Environmental Protection Agency indicate that the amount of priority toxic pollutants found in the influent to publicly owned treatment works (POTWs) served by combined sewers increases significantly during and immediately following a storm event. This study was initiated to document the occurrence, concentration, mass, and source of priority toxic pollutants in combined sewer flows (CSF) and combined sewer overflows (CSO). Samples of precipitation, stormwater runoff, sewerage system sediments, dry weather flow, wet weather combined sewer flow, CSO, and first flush flows were collected from eight selected drainage areas in four cities (two drainage areas per city) and analyzed for priority toxic pollutants and selected conventional and nonconventional pollutants. Municipal water supplies were also sampled to determine background pollutant concentrations. The analytical results for this study indicate:

1. Forty-six priority toxic pollutants were detected in CSO at least once during this study; 11 pollutants were detected greater than 50 percent of the time; and one pollutant, zinc, was detected in 100 percent of the CSO samples. Thirteen of the priority toxic pollutants were detected between 10 percent and 50 percent of the time and 21 of the 46 pollutants detected were present less than 10 percent of the time. Zinc (569 µg/l), nickel (553 µg/l), lead (329 µg/l), copper (263 µg/l), and chromium (117 µg/l) were the toxic elements present in the highest average concentrations; trichloroethene (178 µg/l), methylene chloride (96 µg/l), tetrachloroethene (88 µg/l), 1,1,1-trichlorethane (52 µg/l), and toluene (36 µg/l) were the organic pollutants detected in the highest average concentrations.

2. With the exception of lead, bis(2-ethylhexyl)phthalate and, to a lesser extent, zinc, the average CSO toxic pollutant concentrations were much higher than the CSO median toxic pollutant concentrations.

3. Thirty-six priority toxic pollutants were detected at least once in runoff samples. Of those 36 pollutants, lead (297 µg/l), zinc (274 µg/ℓ), copper (84 µg/ℓ), methylene chloride (32 µg/ℓ), chromium (22 µg/ℓ), and bis(2-ethylhexyl)phthalate (17 µg/ℓ) were detected greater than 50 percent of the time and in the highest average concentrations.

4. Priority toxic pollutant occurrences for the wet weather background, combined sewer flow, and first flush samples generally paralleled the occurrences of toxic pollutants in CSO samples. Zinc, copper, chromium, lead, methylene chloride, toluene, and bis(2-ethylhexyl)phthalate were the priority toxic pollutants detected most frequently. Fifty-two priority toxic pollutants were detected above the analytical detection limit in the combined sewer flow samples, in comparison to 48 and 46 priority pollu-

tants in the wet weather background and first flush samples, respectively. Thirty-two priority toxic pollutants were found in each of these three types of samples.

5. Nineteen priority toxic pollutants were detected at least once in the 13 precipitation samples collected. With the exception of methylene chloride, only zinc, at an average concentration of 52 µg/ℓ, was detected greater than 50 percent of the time in precipitation samples.

6. One tap water sample was collected in each of the four cities where samples were collected. Copper, zinc, chloroform, and methylene chloride were reported in greater than 50 percent of the samples. Chloroform was the toxic organic pollutant present in the highest average concentration (15 µg/ℓ), and zinc was the toxic metal present in the highest average concentration (110 µg/ℓ).

7. CSO pollutant indices (pounds per acre per inch of rainfall) were calculated for the eleven most frequently detected priority toxic pollutants and selected conventional and nonconventional pollutants (BOD_5, TS, TSS and COD). Indices varied widely from drainage area to drainage area, particularly for the toxic organic pollutants.

8. Acid extractable pollutants, base-neutral extractable pollutants [with the exception of bis(2-ethylhexyl)phthalate] and pesticides were not frequently present in the samples collected during this study; when present, the concentrations were generally close to the analytical detection limits for these pollutants.

9. Storm events with an average rainfall intensity in excess of 0.1 inch per hour exhibited a definite first flush period, as defined by the change in conductivity of the wastewater. Storm events with an average intensity of less than 0.1 inch per hour did not exhibit a pronounced first flush period.

10. The average first flush volume for the 13 storm events included in the first flush analysis was 15 percent of the average combined sewer flow for those storm events. Of the average first flush volume, about 35 percent of the flow was discharged as CSO. The remaining 65 percent of the first flush volume was discharged to a POTW. First flush toxic metals and organic pollutant masses averaged 24 percent and 40 percent, respectively, of the CSF toxic mass. However, first flush volumes and toxic pollutant masses associated with the first flush were site specific.

11. Quality assurance results for the CSO study data are good overall. The average of the mean recoveries was 96.1 ± 14.5 percent for volatile organic pollutants; 81.1 ± 23.2 percent for the base-neutral pollutants; 61.3 ± 25.8 percent for acid extractable pollutants; and 97.0 ± 8.0 percent for the toxic metal pollutants. The majority of the toxic organic analyses were performed by isotope dilution (EPA Methods 1624 and 1625). Analytical results obtained using these methods are adjusted based on surrogate recoveries (i.e., pollutant concentrations are automatically

adjusted when this procedure is used). Comparisons between these data and data generated by other analytical methods (i.e., methods 624 and 625) should be undertaken with the difference between these analytical procedures clearly understood.

CONCLUSIONS

The following conclusions are based on results of the evaluations of data obtained during this CSO study:

1. For the eight drainage areas sampled, CSOs represent a substantial contribution of toxic metals discharged to surface waters. The average total toxic CSO metals concentration was 1,890 µg/ℓ and the median CSO total toxic metals concentration was 1,255 µg/ℓ. The average dry weather background total toxic metals concentration at these locations was 4,596 µg/ℓ and the median concentration was 1,724 µg/ℓ.

2. CSO organic priority pollutant discharges are not as significant as CSO toxic metal discharges. The average total toxic organic (TTO) concentration in CSOs was 543 µg/l and the CSO TTO median concentration was 416 µg/ℓ. The average dry weather background total toxic organic concentration was 794 µg/ℓ and the respective median concentration was 304 µg/ℓ.

3. In general, CSO acid extractable, base-neutral extractable, and pesticide pollutant masses were not significant during this study. However, the quantity of these organic toxic pollutant masses in CSOs is site-specific and primarily dependent on the mass of organic toxic pollutants present in the background pollutant masses.

4. CSO toxic volatile organic, base-neutral, and acid extractable pollutant concentrations varied significantly from one drainage area to the next. Median concentrations were almost always much lower than the average concentration for those pollutants. The large difference between median and average concentrations for this database and the variation of organic priority pollutant concentrations by drainage area illustrate that background discharges from sources within the drainage area must be addressed in an evaluation of CSOs. Many other factors also affect the amount of toxic pollutants discharged in CSOs. Extensive evaluations of cause and effect relationships between these factors were beyond the scope of this study. Empirically, however, CSOs are site-specific both in volume and frequency, indicating that land use patterns and sewerage system characteristics should be considered in attempts to estimate the toxic pollutant mass discharge from a drainage area.

5. The concentrations of total solids and total suspended solids in CSOs (376 mg/ℓ and 273 mg/ℓ, respectively) are notable particularly because of the tremendous volume of wastewater that may be discharged as CSO. Average BOD_5 and COD concentrations for CSOs were 65 mg/ℓ and 218 mg/ℓ, respectively.

6. The priority pollutant mass contributed by precipitation is an insignificant portion of the total CSF toxic pollutant mass.

7. The primary source of lead, zinc, and bis(2-ethylhexyl)phthalate in CSO is runoff. Attempts were made to identify factors directly related to pollutant mass in the runoff. Rainfall intensity displayed a linear correlation for zinc and lead. Length of antecedent dry weather conditions did not demonstrate a direct relationship to the runoff pollutant mass.

8. The resuspension of dry weather sediments from combined sewer collection systems accounts for a considerable portion of the CSF toxic pollutant mass. This is an inherent characteristic of combined sewer collection systems which, because they are sized for a wide range of flow rates, often are not designed to maintain a self-cleansing velocity during low-flow dry weather periods. Copper, nickel, chromium, zinc, and lead resuspension masses were 59, 52, 51, 42, and 30 percent of the total CSF mass, respectively. Toxic organic pollutants, while not as prevalent as toxic metals, followed a similar resuspension pattern as the above metals. BOD_5 and COD masses for resuspended material also exceeded 50 percent of the total CSF mass of these pollutants.

9. Toxic pollutants in combined sewer systems may be discharged either to a POTW (via the intercepter system) or to a receiving stream (as CSO). The principal factor that affects the volume and, therefore, the mass of the CSF discharged as CSO is the hydraulic capacity of the regulator chamber, the interceptor sewer, and the associated spur pipe connections (pipe that runs from the regulator chamber to the interceptor). The average percentage of CSF discharged as CSO during the 22 storm events sampled was 57 percent. The total toxic metal mass discharged in CSOs was approximately 56 percent of the CSF total toxic metal mass; and the total toxic organic pollutant CSO mass was approximately 47 percent of the CSF total toxic organic pollutant mass.

10. Characteristics of the first flush samples vary by site. The composition of the first flush samples includes the normal dry weather flow, runoff, and a resuspension of accumulated deposits from both the drainage area and the collection network. Therefore, the first flush sample characteristics are dependent on the residential, commercial, and industrial wastewater; land use; slopes in the drainage area; slopes of the sewers; antecedent dry weather periods; and the intensity of the storm event.

11. Samples were collected during the first flush periods and the toxic pollutant mass for these periods was compared to the CSF toxic pollutant mass for a given storm event. While the toxic pollutant concentrations were normally greater during the first flush than the CSF and CSO average concentrations, the first flush toxic pollutant mass in general was less than half the CSF toxic pollutant mass. For the 13 storm events included in the first flush database, the average total toxic metal mass during the first flush period was 24 percent of the CSF total toxic metal mass. The average total toxic organic pollutant mass during first flush periods was about 40 percent of the CSF TTO mass.

SECTION 2

INTRODUCTION

Combined sewers are conduits that transport domestic wastewater and industrial wastewater during dry weather conditions and domestic wastewater, industrial wastewater, and storm water runoff during wet weather periods. The concept of combined sewers was developed around the turn of the century when the primary objective of collection networks was to transport sewage to the local receiving streams. The use of treatment plants to reduce the impact of dry weather raw sewage on surface waters began during the early twentieth century. The capacity of treatment plants is usually not adequate, however, to handle the voluminous quantities of combined wastewaters that may result during storm events. Wastewater that cannot be handled by the treatment plant is diverted to the receiving waters by means of a diversion structure which is referred to as a regulator chamber. Figure 2.1 graphically displays a typical combined sewer collection network during a storm event.

A hypothetical scenario for a combined sewerage collection system is: wastewater flowing at a dry weather design rate is intercepted at a regulator chamber, conveyed to a publicly owned treatment works (POTW) for treatment, and discharged to the receiving stream. Precipitation begins to fall, first accumulating in depressions and storage areas within the drainage area. The normal dry weather wastewater continues to flow to the POTW; the volume of precipitation continues to increase and the capacity of depressions and storage areas within the drainage area is exceeded, resulting in runoff. The runoff is gentle at first, increasing in velocity and volume as the storm progresses. The runoff contacts dry weather pollutants that have accumulated on the streets, in the gutters, and on the roofs of buildings. The runoff is transported to the sewerage system, combining with the dry weather wastewater. The combined sewer flow enters the regulator chamber that diverts the combined flow to either the treatment plant or, if flows are excessive, directly to the receiving waters untreated. As the storm continues, the volume of combined wastewater discharged to the receiving stream increases. The velocity of the wastewaters in the collection system also increases, resuspending dry weather sediments that accumulated in the sewers. The precipitation ceases and gradually the flow to the regulator chamber decreases. The flow continues to recede until overflow conditions no longer exist.

Combined sewer systems currently serve approximately 1300 communities nationwide. These systems are predominately in the northeastern states, the upper midwestern states and the far western states. Parts of these areas are densely populated urban centers in which millions of people are exposed to the impacts of these overflows(1). The potential health problems to individuals in the communities served by combined sewers and the degradation of the receiving water quality warrant an understanding of the characteristics of CSOs. Numerous studies have been conducted that assess the quantity and quality of CSOs (2, 3, 4, 5, 6, 7, 8, 9, 10). The focus of these studies varied from the fate

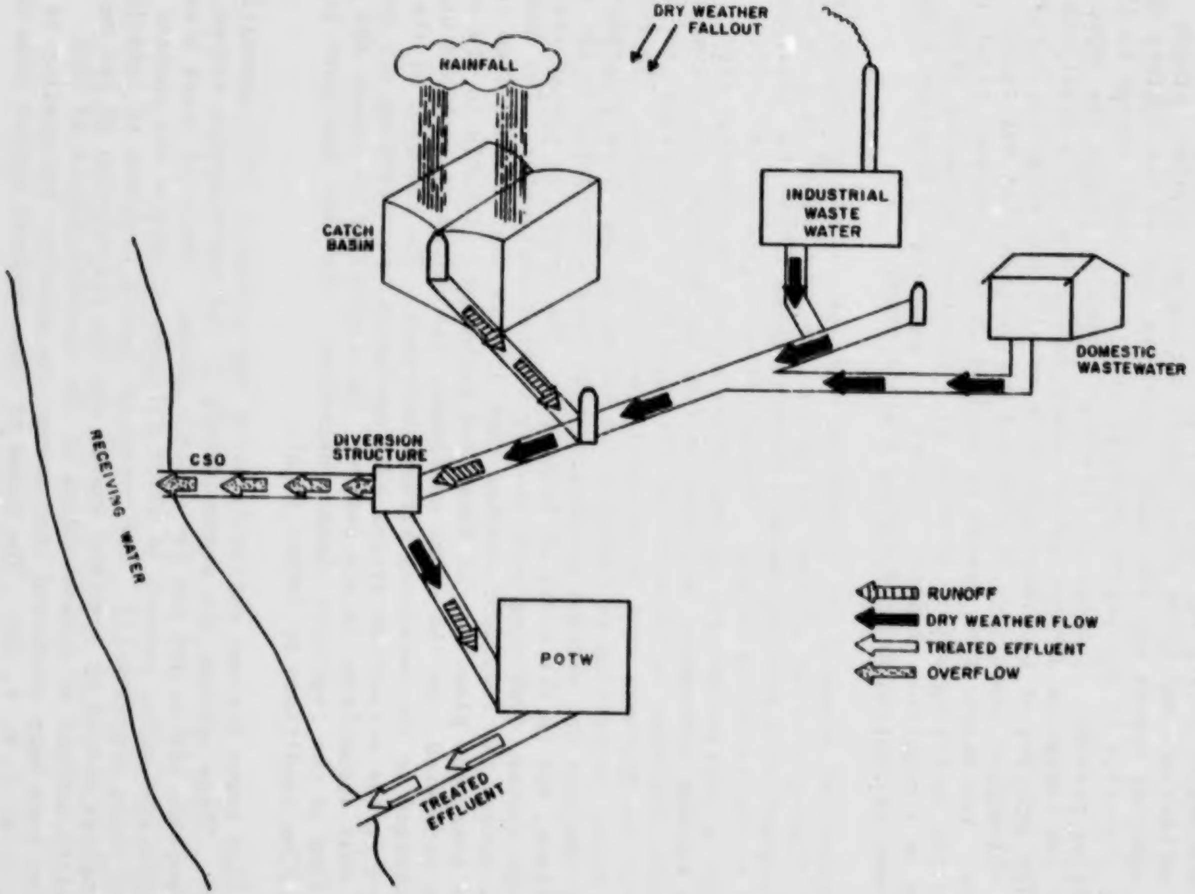

DRY WEATHER FALLOUT
RAINFALL
CATCH BASIN
INDUSTRIAL WASTE WATER
DOMESTIC WASTEWATER
DIVERSION STRUCTURE
CSO
RECEIVING WATER
POTW
TREATED EFFLUENT
RUNOFF
DRY WEATHER FLOW
TREATED EFFLUENT
OVERFLOW

FIGURE 2.1 TYPICAL COMBINED SEWER COLLECTION NETWORK DURING A STORM EVENT

of particulates discharged in CSOs to microorganisms present in such wastewaters. While a number of studies have investigated the presence of toxic metals in CSOs, few is any studies have been undertaken to assess the presence of priority toxic pollutants in CSOs.

To determine the source, occurrence, and fate of priority toxic pollutants in sewerage systems and in POTWs, EPA initiated several related studies. In one study, the source (residential, commercial, or industrial) of priority toxic pollutants in the influent to POTWs was evaluated (11). A second study addressed the occurrence and fate of priority toxic pollutants in 40 POTWs with different treatment processes and diversified industrial wastewater contributions; this study was later expanded to include 10 additional POTWs, each with only one significant industrial discharger (12). A third study evaluated the occurrence and fate of priority toxic pollutants in a POTW for 30 consecutive days; the influent pollutant variability for the 30-day period was compared to the pollutant variability observed during a previously conducted six-day sampling period (13). A fourth study is currently being conducted through the Nationwide Urban Runoff Program to assess the occurrence of priority toxic pollutants in urban runoff. Collectively, these studies provide much information on the source, occurrence, and fate of priority toxic pollutants in sewerage systems and in POTWs. This study addresses the topic of priority toxic pollutants in CSOs, a subject not covered in previous POTW studies.

Because this study represents the first effort to specifically assess priority pollutants in CSOs, development of a sampling protocol was necessary before a full-scale investigation could be undertaken. A pilot study was initiated, therefore, during the summer of 1981 that aided in the establishment of a sampling protocol for this study (14). The pilot study program was tailored to develop a sampling plan to obtain information on the magnitude, source, and fate of the priority toxic pollutants in combined sewer collection systems during wet weather conditions.

PURPOSE

The purposes of this CSO toxic pollutant study are: 1) to document the occurrence, concentration, and mass of priority toxic pollutants in CSOs; 2) to determine the sources of priority toxic pollutants in combined sewer flows (i.e., identify the percentage of the pollutant mass attributable to dry weather wastewater flows, runoff, and resuspension of the accumulated sediments within the collection network); 3) to determine the fate of priority toxic pollutants in combined sewer collection systems (i.e., identify the percentage of the total pollutant mass discharged to the POTW and the percentage of the wet weather flow discharged directly to the receiving waters); and 4) to evaluate any observable correlations between priority toxic pollutant mass and land use, rainfall intensity, slope of the catchment area, or other physical factors.

SCOPE OF WORK

This CSO toxic pollutant study contained six major tasks. They are:

1) select representative catchment areas for sampling;
2) sample the selected catchment areas during dry weather background periods to establish a baseline datum and subsequently during wet weather conditions;
3) collect sediment samples during dry weather conditions from the collection system;
4) analyze the collected samples for priority toxic pollutants and for specified conventional and nonconventional pollutants;
5) compile the analytical results in a computerized data management file-structured system; and
6) evaluate the data and prepare a final report.

SECTION 3

SITE SELECTION

To assess the presence, source, quantity, and fate of priority pollutants in combined sewer flows and combined sewer overflows on a nationwide basis, criteria were established to ensure selection of drainage areas that are amenable to the objectives of the study. As a result of a CSO pilot study, which was conducted during the summer and fall of 1981 in Newark, NJ and Brooklyn, NY, criteria were developed for this CSO study. These criteria are:

1. The study areas selected should be served only by combined sewers. Although pertinent information could be obtained by sampling separated collection networks and extrapolating data to simulate a combined sewer overflow, more representative data would be obtained by sampling drainage areas served by combined sewers.

2. The municipality responsible for the combined sewer system should be willing to participate in the study. Experienced personnel employed by the local municipality can provide pertinent information that otherwise may not be available on potential sample locations. Communication directly with the field crews responsible for the operation and maintenance of the regulators is desirable.

3. Catchment areas must have well-defined boundaries. This is necessary not only to measure the quantity of priority pollutants in CSOs, but also to identify the source of the pollutants and any observable correlations that may exist between pollutant mass and land use, rainfall intensity, and other parameters.

4. Catchment areas selected should be served by a single regulator to reduce the number of samples that must be collected (a major consideration for priority pollutant sampling) and to reduce the field crew manpower requirements. Catchment areas with relief lines that do not discharge to the regulator chamber should be avoided, as well as catchment areas served by multiple regulators.

5. Selected regulator locations should be arranged such that both the combined sewer flows (CSF) and combined sewer overflows (CSO) are accessible and adaptable for sampling. In particular, regulator sample locations should be free of potential surcharge conditions as a result of tidal influences or river flooding.

6. Selected regulator locations should be arranged such that the CSF, CSO, and flow to the POTW can be accurately monitored. Locations where flow calibration monitoring has been previously conducted should be given priority consideration. Similarly, locations with flow monitoring or level monitoring equipment in-place or where such equipment can be easily adapted should be evaluated first.

7. Catchment areas should contain some industrial/commercial facilities that would be expected to have priority pollutants in their wastewater. Diversified land use that includes residential, commercial, open space (parks, etc.), and a mix of industries is desired.

8. Historical information such as plans of the regulator chamber, drainage area acreage, land use, industries tributary to sample locations, slopes of the catchments, and frequency of overflows should be available.

9. The regulator chamber's sensitivity to overflow conditions should be considered. The in-line storage capacity of the collection system should not be so large that overflows are limited to high intensity storm events.

10. Proximity of catchment areas to existing recording rain gauges should be determined. Because storm intensities are a major consideration in a CSO study, availability of an existing recording rain gauge within the selected catchment areas is an asset.

11. Size and shape of the catchment area should be considered. The catchment area should be large enough so that it is not dominated by a single industry (an atypical system), yet small enough to be manageable for sampling and flow monitoring.

12. Accessibility of the regulator should be evaluated. Regulators situated at the intersection of major traffic arteries are not attractive sample locations due to the potential delays and additional manpower needed for traffic control.

13. Safety of the sample crews and field equipment should be a primary consideration.

Approximately 60 communities account for over 80 percent of the area in the 1300 communities served by combined sewers. Those 60 communities were contacted to appraise their willingness to participate in this CSO study and to further evaluate the suitability of drainage areas within those communities with respect to the above.

As a result of this initial screening, over 30 communities were eliminated from further consideration. The remaining 30 communities were evaluated in detail and the 13 communities which appeared to best meet the program objectives were selected for field reconnaissance inspections. Potential sample locations were physically inspected for their applicability to flow monitoring and sample collection. The drainage areas were defined on plan drawings and then redefined in the field. In addition, available historical information on industries tributary to the potential sampling locations, the sensitivity of the regulators at those locations to overflow, flow information, and the slopes of the sewers were reviewed.

Eight catchment areas were selected for sampling in four cities. These areas represent diversified land use; however, none of the catchment areas selected are "purely" residential, commercial or industrial in nature. The selected catchment areas were in: Providence, Rhode Island; Seattle, Washington; St. Louis, Missouri; and St. Paul, Minnesota. Some important characteristics of the selected catchment areas are summarized in Table 3.1.

TABLE 3.1. CHARACTERISTICS OF SELECTED CATCHMENT AREAS.

LOCATION	TRAFFIC VOLUME	LAND USE DESCRIPTION	REGULATOR ARRANGEMENT	MAJOR INDUSTRIES IN CATCHMENT AREA (Standard Industrial Classification Code)
Ernest at Allens-Providence, RI	Moderate	65 acres of industrial and multi-family residential land use; catchment area is highly impervious.	Weir and orifice structure	2-electroplating facilities (3471); 12-coating & engraving facilities; 2-miscellaneous plastics manufacturer (3079).
Dexter at Huntington-Providence, RI	Light	300 acres of predominately multi- and single-family residential with scattered commercial and industrial activities.	Horizontal slot and dam	5-electroplating facilities (3471); 2-coating and enameling services (3479); 1-tool and die manufacturer (3544); 1-fabricated metal manufacturer (3490); 1-watch maker (3873); 1-jewelry manufacturer (3915); 1-fastener manufacturer (3960); 1-dry cleaning operation (7216).
Lander-Seattle, WA	Heavy	500 acres of light to medium industrial and mixed commercial activities.	Pneumatically operated sluice gates controlled by the CATAD system	Brewery (2082), meat packing (2011), metal plating (3471), and battery manufacturing (3691).
Michigan-Seattle, WA	Heavy	745 acres of heavy commercial and mixed industrial/residential land use.	Pneumatically operated sluice gates controlled by the CATAD system.	Metal plating (3471), dry cleaning (7216), chemical manufacturing (2861), repair service (7699), pet food processing (2047) and glass manufacturing.
Branch-St. Louis, MO	Moderate	2,580 acres, of which about 80 percent is residential/commercial; 13 percent is industrial; and seven percent is open space.	Slot and weir regulator	5-machinery manufacturers (3592,3599,3544); plastics processor (3079); rubber manufacturer (3069,3061); 8-plants which fabricate metal products (3431,3432,3446,3471,3441,3479); 3-electrical supplies manufacturer (3613,3643); leather tanning facility (3149,2851); foundaries (3321,3362,3398); printing and publishing (2751, 2799,2711); 8-meat processors (2011,2013); oils and fats processor (2077); misc. food processors (2099); paint manufacturer (2751,2799).
Prairie-St. Louis, MO	Moderate	518 acres, of which 50 percent is commercial/residential; 40 percent is industrial; and 10 percent is open space.	Slot and weir regulator	4-plants which fabricate metal products (3471, 3479,3494); 2-machinery manufacturers (3533,3599); 2-plastics processing plants (3079); sporting goods manufacturer; 3-chemicals and allied product processors (2851,2891,2834); 2-meat packing plants (2011,2013); paper and allied products company (2653).
Phalen-St. Paul, MN	Light	870 acres of scattered industrial, commercial land use with the majority of the area being multi-family residential and open area.	Orifice and weir arrangement	Malt beverage (2082), surgical appliances (3842), malleable iron foundry (3322), asphalt felt and coating (2952), meat processing (2013), refrigeraters and vacuum cleaners (3585,3632,3635).
Eustis-St. Paul, MN	Light	78 acres of light industrial and commercial land use. Area is highly impervious.	Leaping weir	Inorganic chemicals (2816), truck trailer manufacturing (3715), welding repair (7692), metal coating (3479), and battery manufacturing (3691).

SECTION 4

DESCRIPTION OF SELECTED CATCHMENT AREAS

PROVIDENCE, RHODE ISLAND

The city of Providence is located in northern Rhode Island at the head of upper Narragansett Bay. The entire city is served by combined sewers. The towns of North Providence and Johnston have separated wastewater collection systems that discharge into the Providence combined sewer system. The entire service area, including Johnston and North Providence, is approximately 50 square miles in area. In May 1982, the Narrangansett Bay Water Quality Management District Commission assumed responsibility for the maintenance of the Providence sewer network and the operation of Providence's municipal treatment facility.

Providence lies within the New England lowland region and encompasses an area of 20 square miles. The downtown area is generally flat, with the highest elevation just over 50 feet above mean sea level. The rest of the city is covered by hills, all less than 200 feet above sea level. The streams that drain Providence are the Woonasquatucket River, Moshassuck River, Seekonk River, West River, and Providence River (15). The average annual precipitation for the Providence area totals approximately 41 inches.

The service area for Providence's municipal treatment facility collection network includes approximately 393 miles of sewers: 168 miles of combined sewers, 137 miles of sanitary sewers, and 88 miles of separate storm sewers. Sewers in this system range in size from eight to 110 inches in diameter. The majority of the larger sewers (greater than 18 inches) are constructed of brick, while the smaller diameter sewers are either vitrified clay or brick. The depth of the sewers ranges from seven to 65 feet with an average depth of approximately 12 feet. The normal distance between manholes is 200 feet with two manholes located at each intersection. There are three pumping stations in the collection network. The sewerage system includes 65 overflow structures that discharge to the Providence River and its tributaries during wet weather conditions (16).

Most overflow regulator structures consist of a slot and tide gate arrangement. When the slot capacity is exceeded, the excess flow bypasses the slot and discharges to the receiving waters via the overflow pipe. The tide gates, where required, exclude seawater inflow into the system during tidal fluctuations. The sewerage system was designed to accommodate a rainfall of one inch per hour in addition to the domestic wastewater and groundwater flows (15).

Due to tidal fluctuations, flow monitoring at the majority of the regulators adjacent to the receiving streams is affected by river backwater flows. The two regulators that were free from these influences and determined suitable for the CSO study are located at the intersection of Ernest Street and Allens Avenue and the intersection of Dexter Street and Huntington Avenue. Figure 4.1 shows the geographical location of the catchment areas sewered by these two regulators.

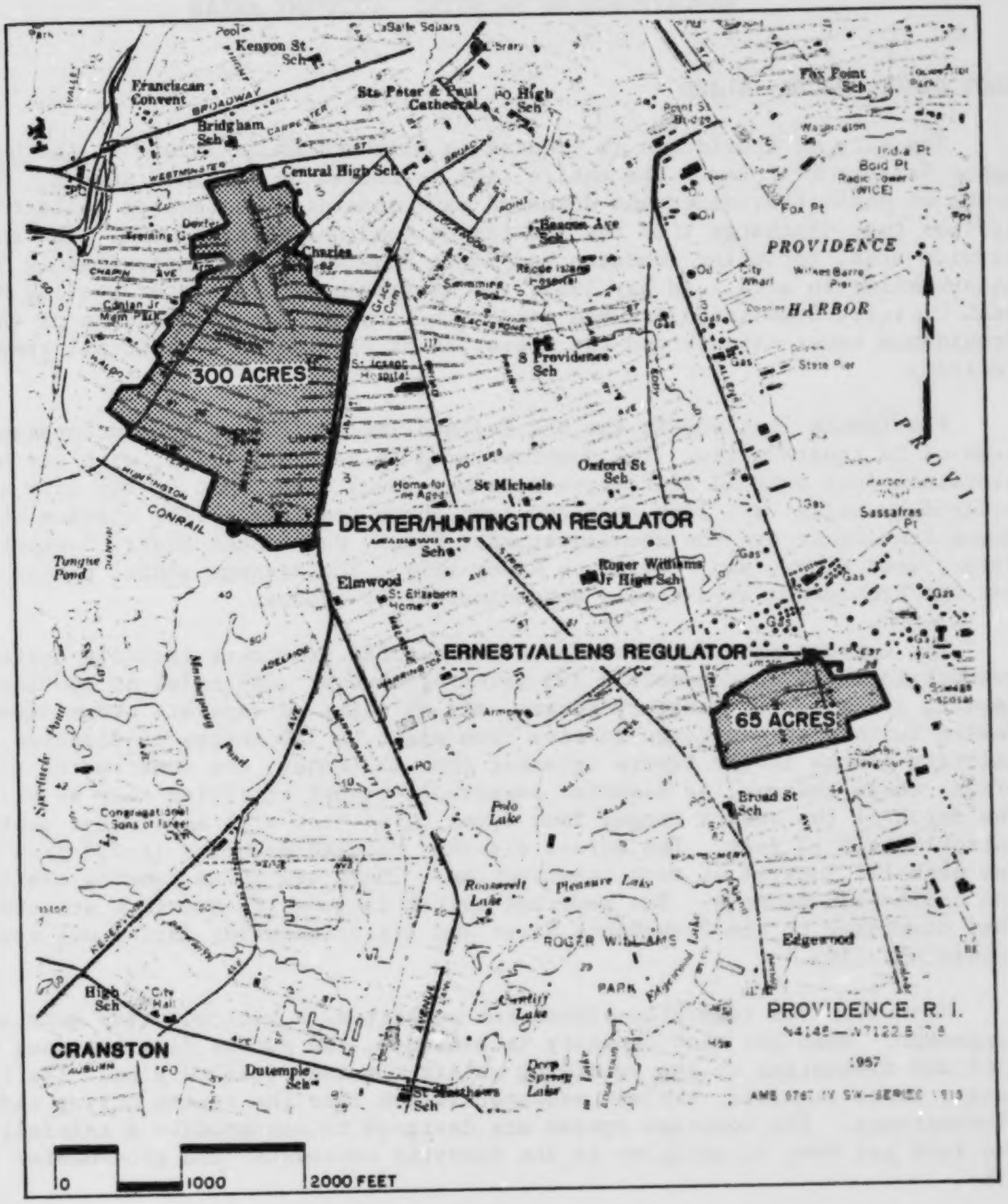

300 ACRES
DEXTER/HUNTINGTON REGULATOR
ERNEST/ALLENS REGULATOR
65 ACRES
PROVIDENCE
HARBOR
N
CRANSTON
PROVIDENCE, R. I.
1957
Kenyon St. Sch
Franciscan Convent
Bridgham Sch
Sts Peter & Paul Cathedral
Central High Sch
Fox Point Sch
Beacon Ave Sch
S Providence Sch
Oxford St Sch
St Michaels
Elmwood
Roger Williams Jr High Sch
Broad St Sch
Tongue Pond
Mashapaug Pond
Spectacle Pond
Polo Lake
Roosevelt Lake
Pleasure Lake
ROGER WILLIAMS PARK
Edgewood
Sassafras Pt
State Pier
CONRAIL
HUNTINGTON
High Sch
Dutemple Sch
0
1000
2000 FEET

FIGURE 4.1 GEOGRAPHICAL LOCATION OF THE DEXTER STREET AT HUNTINGTON AVENUE AND ERNEST STREET AT ALLENS AVENUE DRAINAGE AREAS

Ernest Street at Allens Avenue

The Ernest Street at Allens Avenue regulator (Ernest @ Allens) overflows to the Providence River. The area served by the regulator consists of approximately 65 acres that is partly residential and highly industrialized. Metal finishing and plating operations dominate the catchment area while jewelry crafting and plastic processing are secondary industries. The drainage area is bisected by Allens Avenue, a heavily travelled riverfront artery that accommodates a good deal of truck traffic. The section east of Allens Avenue is comprised of single and multi-family dwellings; the area west of Allens Avenue is predominantly industrial development. Table 3.1 summarizes several of the characteristics of the drainage area, including the industries discharging to the overflow regulator. The western section of the drainage area is largely covered by roofed structures and parking lot surfaces and is therefore highly impervious.

Localized flooding was observed in the drainage area during storm events as a result of numerous clogged catchbasins and storm water inlet structures. Depending on the intensity and volume of rainfall for a given storm event, various quantities of runoff from this drainage area bypassed the clogged storm inlet structures and flowed to adjacent drainage areas. The clogged inlet structures, in addition to diverting some runoff to adjacent areas, also resulted in the temporary storage of storm water in the catchment area.

Sections of the brick and mortar sewers in the catchment area are severely damaged in a number of locations, presumably the result of years of contact with acidic wastewaters from the local industries. Several sections of sewers have been reconstructed because of the complete deterioration of the mortar joints. Areas in which vitrified clay sewers were used appear to be in much better structural condition.

A steeply sloped 24-inch concrete trunk sewer runs north along Allens Avenue to the regulator chamber. This sewer tapers to a 12-inch spur pipe that discharges to the interceptor paralleling Ernest Street. As Figure 4.2 illustrates, a manhole (A) is located upstream of the regulator chamber manhole (B) while a second manhole (C) is located downstream of the regulator chamber on the overflow line. During wet weather periods, the combined domestic and storm water flow discharges to the interceptor via the 12-inch spur pipe. As the flow increases and the capacity of the spur pipe is exceeded, the flow spills over the trough in manhole B and flows through a two foot square opening to manhole C. Surcharge conditions develop as a result of a concrete weir constructed in the manhole which eliminates tidal inflow during high tide periods. The combined sewer flow ultimately overflows the 18-inch high weir and is discharged to the Providence River.

Dexter Street at Huntington Avenue

The Dexter Street at Huntington Avenue regulator (Dexter @ Huntington) likewise overflows to the Providence River. Approximately 300 acres of single family residential and scattered industrial development are tributary to this regulator. Metal finishing and electroplating are the primary industries in

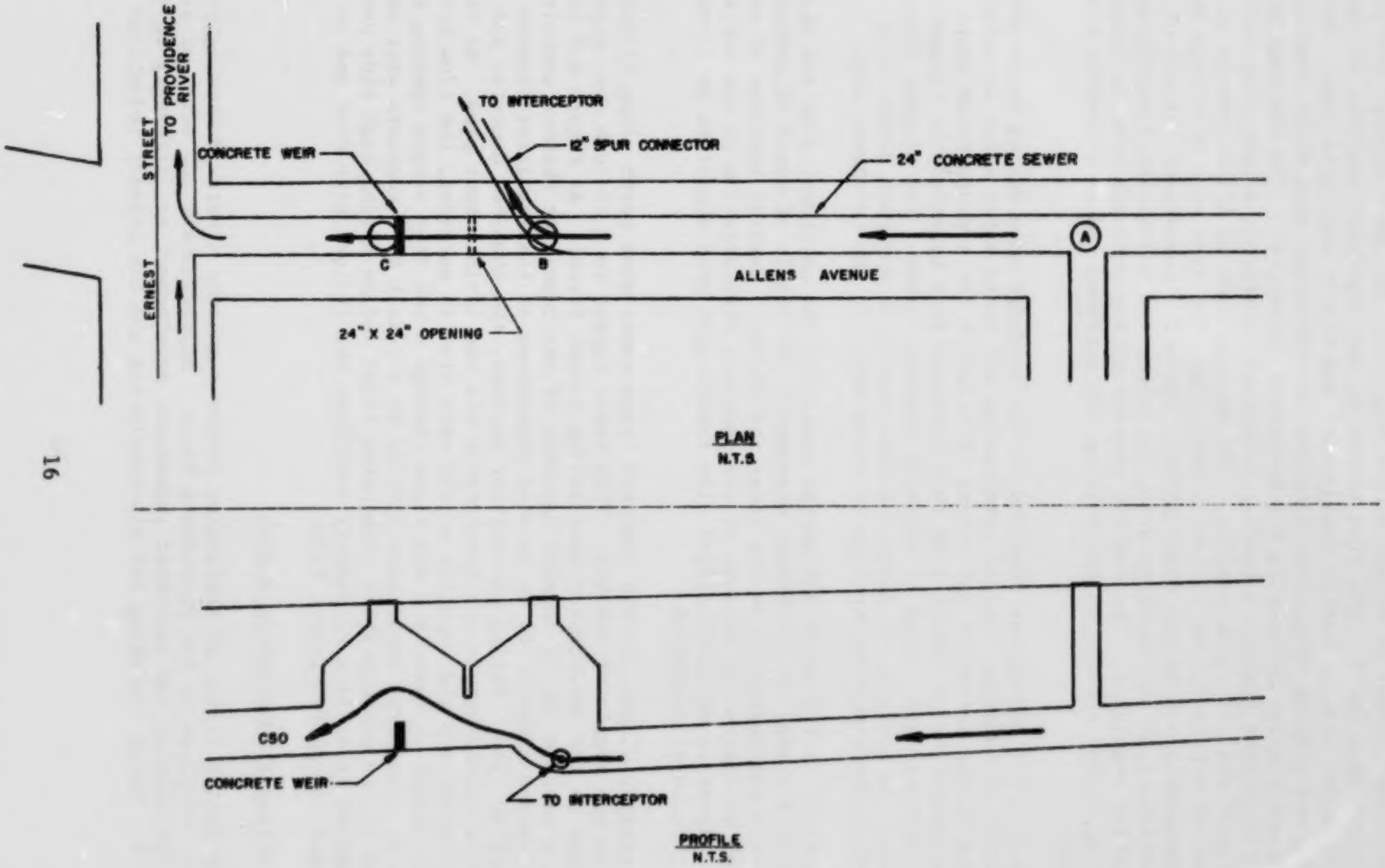

TO PROVIDENCE RIVER
STREET
ERNEST
CONCRETE WEIR
TO INTERCEPTOR
12" SPUR CONNECTOR
24" CONCRETE SEWER
Ⓐ
C
B
ALLENS AVENUE
24" X 24" OPENING
PLAN
N.T.S.
CSO
CONCRETE WEIR
TO INTERCEPTOR
PROFILE
N.T.S.

FIGURE 4.2 REGULATOR CHAMBER ARRANGEMENT AT THE INTERSECTION OF ERNEST STREET AND ALLENS AVENUE

the drainage area. Traffic volume in general is low, most traffic is limited to local travel.

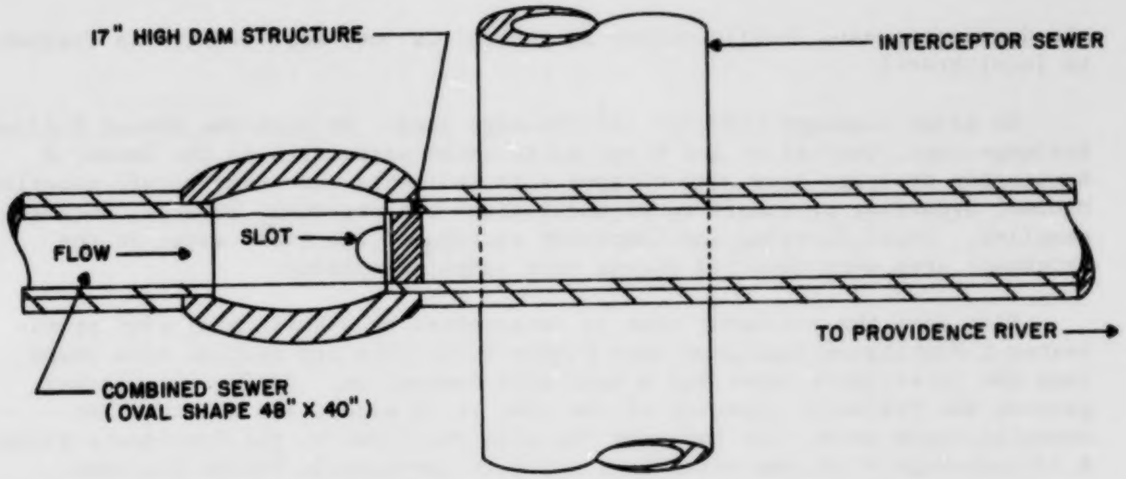
No major highways traverse the drainage area. As with the Ernest @ Allens drainage area, several of the storm water inlet structures in the Dexter @ Huntington drainage area were clogged with sediments and other runoff material. Minimal bypassing of runoff to adjacent areas was observed, however, during sampling. Local flooding and temporary storage of the storm water in the catchment area were observed during each sampling episode.

Flow from the catchment area is intercepted by a horizontal slot at the Dexter @ Huntington regulator (see Figure 4.3). The dry weather flow drops into the interceptor sewer via a spur pipe connection. During wet weather periods the hydraulic capacity of the slot is exceeded, and the combined domestic/storm water flow bypasses the slot and flows to the Providence River. A 17-inch-high brick dam structure, which is immediately behind the semicircular slot opening, reduces the number of dry weather overflow occurrences. The slot regulator and associated spur pipe have a limited hydraulic capacity in excess of the average dry weather flow. This point was substantiated in July when water from a nearby fire hydrant was sufficient to cause an overflow occurrence. Table 3.1 presents the characteristics of the drainage area.

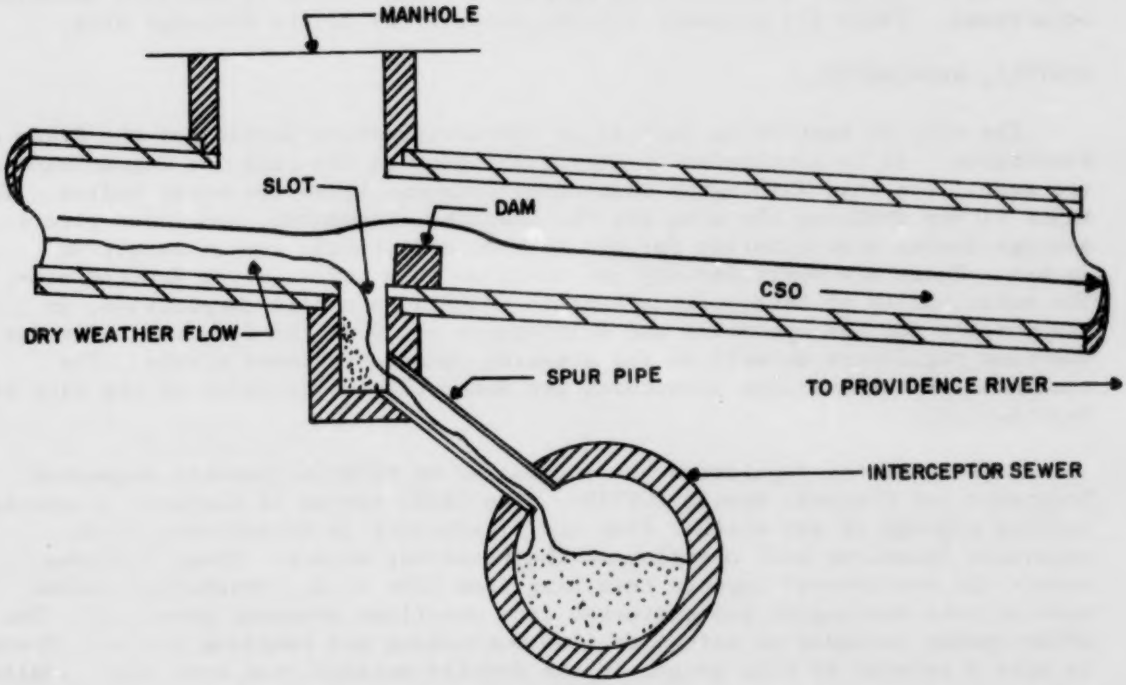
SEATTLE, WASHINGTON

The city of Seattle is located in the northwestern portion of the State of Washington. It is surrounded by Lake Washington on the east and Puget Sound on the west. The Lake Washington ship canal connects these two water bodies. The major rivers draining the area are the Duwamish, Sammamish, and Cedar rivers. Average annual precipitation for the Seattle area totals approximately 40 inches. There are approximately 160 overflow structures in the Seattle area. The municipality of Metropolitan Seattle (METRO), a public corporation, is responsible for the operation and maintenance of 30 of the 160 combined sewer overflow regulators as well as the areawide sewage treatment plants. The remainder of the overflow structures are under the jurisdiction of the city of Seattle (17).

Fifteen of the regulators are controlled by METRO's Computer Augmented Treatment and Disposal System (CATAD). The CATAD system is designed to provide in-line storage of wet weather flow and flexibility in determining which regulator locations will overflow to the receiving waters. These features reduce the detrimental impacts resulting from CSOs (i.e., freshwater bodies such as Lake Washington are protected from overflows whenever possible). The CATAD system includes an extensive flow monitoring and sampling system. There is also a network of rain gauges in the Seattle metropolitan area that, similar to the flow monitoring and sampling equipment, are all connected to a central computer by a telemetry control unit (TCU). Each flow monitoring and precipitation gauge location is monitored every 10 seconds. Based on the information from the flow monitors and rain gauges, the CATAD system either initiates, increases, decreases, or stops wet weather overflows. Frequency of overflow is currently estimated at 40 occurrences per outfall per year on the average (3).


17" HIGH DAM STRUCTURE
INTERCEPTOR SEWER
SLOT
FLOW
TO PROVIDENCE RIVER
COMBINED SEWER
(OVAL SHAPE 48" X 40")

PLAN
N.T.S.


MANHOLE
SLOT
DAM
CSO
DRY WEATHER FLOW
SPUR PIPE
TO PROVIDENCE RIVER
INTERCEPTOR SEWER

PROFILE
N.T.S.

FIGURE 4.3 DEXTER AT HUNTINGTON
REGULATOR ARRANGEMENT

Following inspections of several of the overflow regulators, the Lander Street and Michigan Street regulators were selected for sampling as part of this CSO study. Table 3.1 presents the characteristics of the drainage areas sewered by those regulators. Figure 4.4 presents the geographical location of the drainage areas with respect to the Seattle metropolitan area. Both regulators are part of the METRO CATAD system. For the purpose of this study, the CATAD system was programmed in such a way that in-line storage of the wet weather flow at the selected regulators was eliminated.

Lander Street

Five hundred acres of predominantly industrial land comprise the drainage area of the Lander Street regulator. Major industries include a brewery, a meat packing plant, various food processing plants, a metal plating operation, and a battery manufacturing plant. The drainage area is largely impervious and is subjected to scattered truck traffic serving the local industries as well as heavy automobile traffic from Interstate 5 and East Marginal Way, both major thoroughfares to downtown Seattle. A series of railroad yards parallels Interstate 5 and East Marginal Way running north to south through the drainage area. With the exception of Beacon Hill on the eastern border, the drainage area is only slightly sloped.

Wastewaters from the Lander drainage area flow into a common concrete sewer. The trunk sewer discharges to a rectangular concrete regulator chamber. As seen in Figure 4.5, dry weather sewage is discharged to the interceptor system that ultimately conveys the wastewater to the municipal treatment plant. During wet weather conditions, the CATAD system has several operation alternatives. First, the sluice gate to the municipal treatment plant could be closed and the sluice gate to the East Waterway opened, thus resulting in a CSO. Second, both sluice gates could be closed, thus maximizing in-line storage. Third, both sluice gates could be opened. And fourth, any combination of the three previous alternatives could be arranged. The sluice gates can be controlled manually or programmed to open or close at a fixed flow elevation. During the CSO toxic pollutant study, the sluice gate to the POTW was opened and the sluice gate to the East Waterway was programmed to remain closed until surcharge conditions reached a predetermined elevation. The predetermined elevation was based on historical information and was selected to minimize in-line storage. When wastewater reached that elevation, the overflow sluice gate opened, the sluice gate to the municipal treatment plant closed, and wastewater "overflowed" to the East Waterway.

Continuous level recorders (bubbler tubes) are in place on both the incoming and outgoing interceptor sewers at the regulator chamber. Stage versus discharge relationships were developed for both of these sewers. The regulator chamber is accessible inside the existing regulator control building. The overflow sewer can be affected by tidal fluctuations in the bay. However, the tide elevations during the storm events sampled did not affect the sampling program for this study.

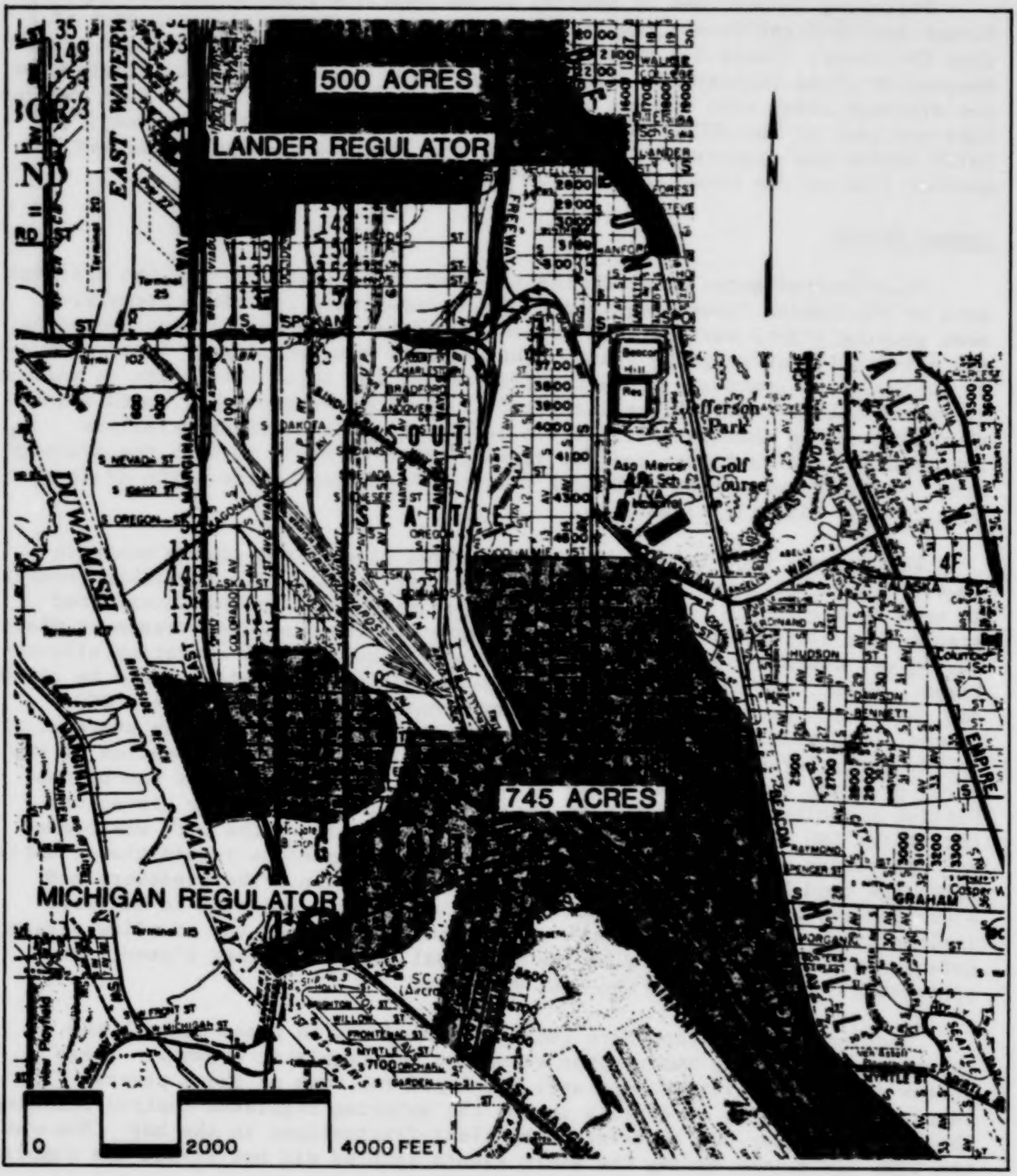

500 ACRES
LANDER REGULATOR
745 ACRES
MICHIGAN REGULATOR
N
0
2000
4000 FEET
EAST WATERWAY
DUWAMISH
WATERWAY
FREEWAY
Golf Course
Terminal 25
Terminal 102
Terminal 107
Terminal 115
EMPIRE
GRAHAM
HUDSON
BEACON
SPOKANE
DAKOTA
ALASKA ST
EAST MARGINAL

FIGURE 4.4 GEOGRAPHICAL LOCATION OF LANDER AND MICHIGAN DRAINAGE AREAS

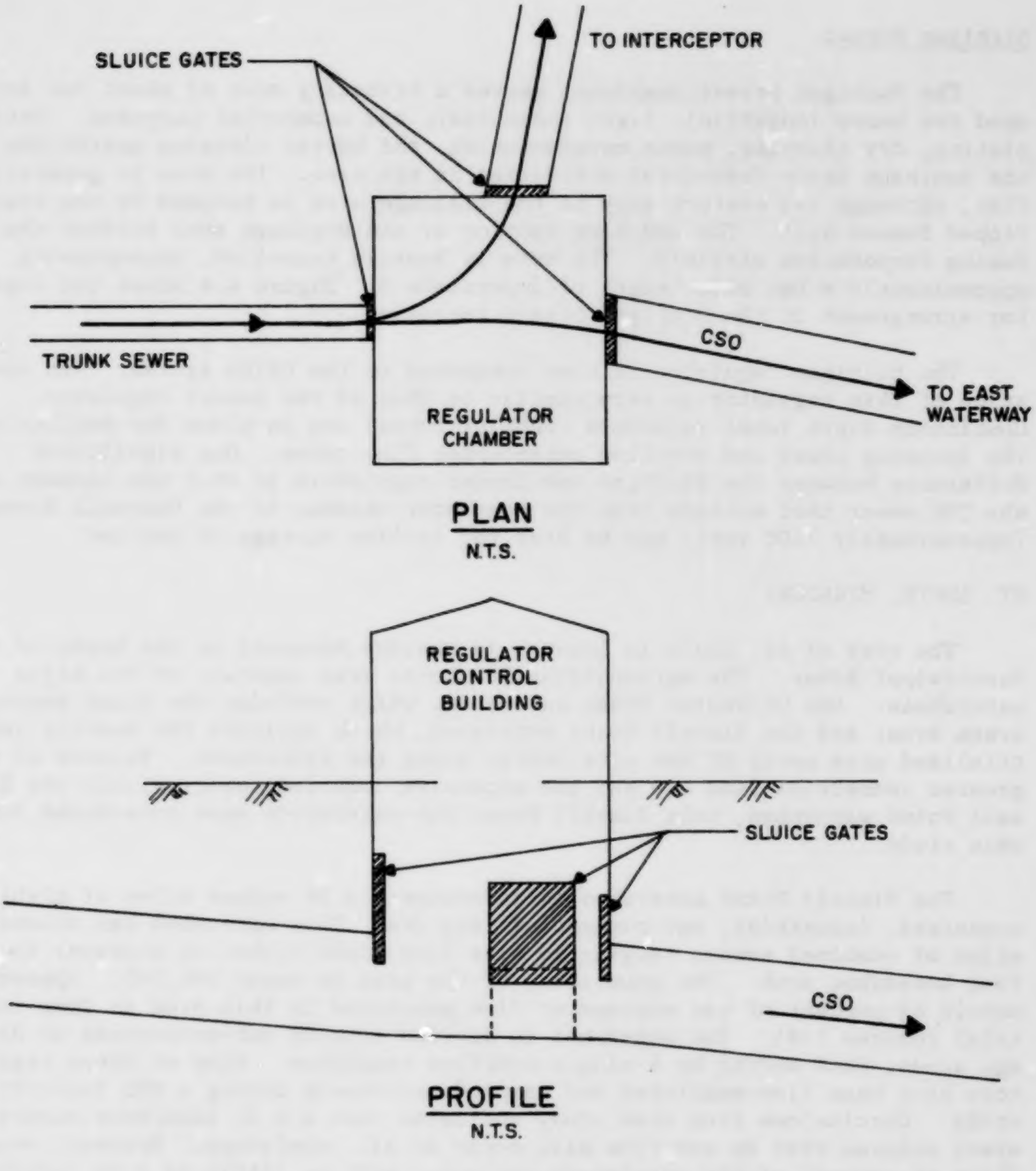

SLUICE GATES
TO INTERCEPTOR
TRUNK SEWER
CSO
TO EAST WATERWAY
REGULATOR CHAMBER
PLAN
N.T.S.
REGULATOR CONTROL BUILDING
SLUICE GATES
CSO
PROFILE
N.T.S.

FIGURE 4.5 LANDER REGULATOR ARRANGEMENT

Michigan Street

The Michigan Street regulator serves a tributary area of about 745 acres used for heavy industrial, light industrial, and commercial purposes. Metal plating, dry cleaning, paint manufacturing, and barrel cleaning operations are the dominant heavy industrial activities in the area. The area is generally flat, although the eastern edge of the drainage area is bounded by the steeply sloped Beacon Hill. The southern section of the drainage area borders the Boeing Corporation airfield. The area is heavily travelled, encompassing approximately a two mile length of Interstate 5. Figure 4.6 shows the regulator arrangement at the Michigan Street location.

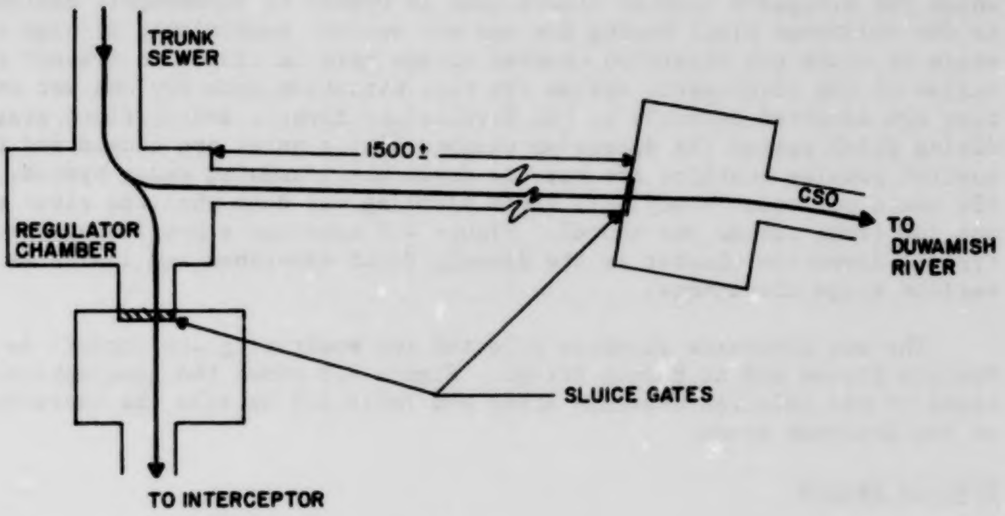
The Michigan regulator is also connected to the CATAD system. The operation of this regulator is very similar to that of the Lander regulator. Continuous depth level recorders (bubbler tubes) are in place for monitoring the incoming sewer and overflow interceptor flow rates. One significant difference between the Michigan and Lander regulators is that the segment of the CSO sewer that extends from the regulator chamber to the Duwamish River (approximately 1500 feet) may be used for in-line storage if desired.

ST. LOUIS, MISSOURI

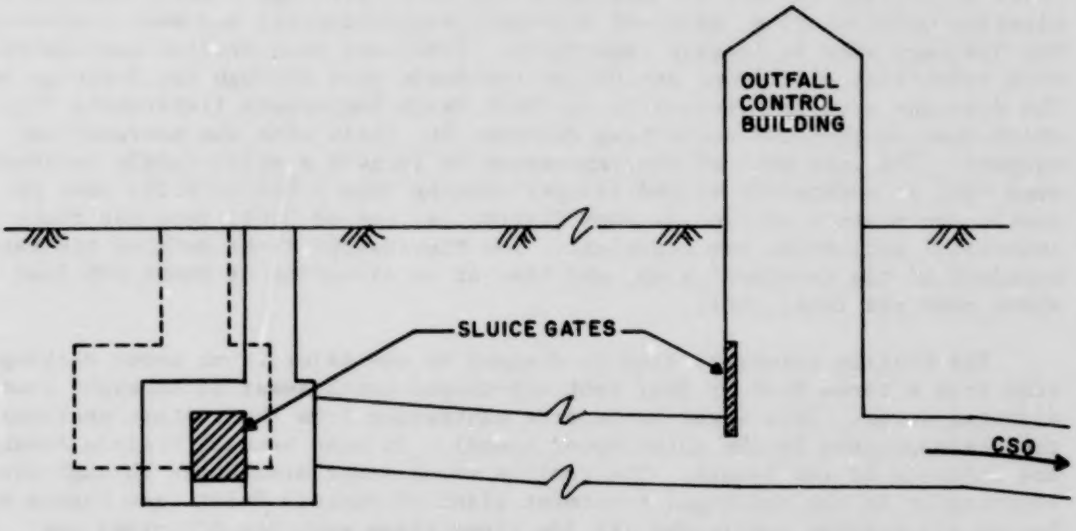
The city of St. Louis is located in eastern Missouri on the banks of the Mississippi River. The metropolitan St. Louis area consists of two major watersheds: the Coldwater Creek watershed, which includes the older downtown urban area; and the Bissell Point watershed, which includes the heavily industrialized area north of the city center along the waterfront. Because of the greater industrial land use and the extensive combined sewers within the Bissell Point watershed, only Bissell Point sub-watersheds were considered for this study.

The Bissell Point watershed is approximately 34 square miles of highly urbanized, industrial, and commercial land use. This watershed has around 700 miles of combined sewers ranging in size from eight inches in diameter to a 38 foot horseshoe arch. The population of the area is about 500,000. Approximately 45 percent of the wastewater flow generated in this area is from industrial sources (18). The watershed is divided into 23 sub-watersheds or drainage areas, each served by a single overflow regulator. Nine of these regulators have been flow-monitored and sampled previously during a CSO facility plan study. Conclusions from that study indicated that a 0.25 inch/hour rainfall event ensures that an overflow will occur at all regulators. However, overflows at several of the regulators may occur with as little as 0.04 inch/hour of rainfall (19).

Treatment and disposal of wastewaters generated in the Bissell Point watershed is affected directly by the stage elevation of the Mississippi River. An extensive network of diversion chambers, sluice gates, floodwalls, and pumping stations have been constructed to maximize treatment of wastewaters, yet minimize the inflow of seasonal flood waters at the treatment plant. In general, three treatment and disposal modes of operations exist for the drainage areas serviced by the flood control facilities: 1) low river stage in


TRUNK
SEWER
1500±
CSO
TO
DUWAMISH
RIVER
REGULATOR
CHAMBER
SLUICE GATES
TO INTERCEPTOR

PLAN
N.T.S.


OUTFALL
CONTROL
BUILDING
SLUICE GATES
CSO

PROFILE
N.T.S.

FIGURE 4.6 MICHIGAN REGULATOR ARRANGEMENT

which the diversion chamber sluice gate is opened to accommodate maximum flow to the treatment plant during dry and wet weather conditions; 2) high river stage in which the diversion chamber sluice gate is closed to prevent river inflow to the interceptor system (in this situation both dry and wet weather flow are diverted directly to the Mississippi River); and 3) flood stage, during which period the diversion chamber sluice gates are closed and the flood control pumping stations are used to drain the inundated sewer system. For the CSO toxic pollutant study, all field sampling was done when the river elevation was low (mode number one above). Figure 4.7 contains a profile view of a typical diversion chamber in the Bissell Point watershed and indicates the various stage elevations.

The two diversion chambers selected for monitoring are located on East Prairie Avenue and on Branch Street. Figure 4.8 shows the geographical locations of the selected drainage areas and Table 3.1 details the characteristics of the drainage areas.

Prairie Avenue

The Prairie Avenue drainage area is comprised of approximately 518 acres, of which, about 50 percent is used for residential and commercial purposes , 40 percent is industrial land use, and 10 percent is open area. The major industrial activities in this drainage area are metal plating, organic chemicals/ plastics manufacturing, soap and detergent manufacturing, and meat processing. The drainage area is largely impervious. Truck and rail traffic associated with industrial riverfront activities routinely pass through the drainage area. The drainage area is bisected by the Mark Twain Expressway (Interstate 70), which runs north-south connecting downtown St. Louis with the metropolitan airport. The area west of the expressway is largely a multi-family residential area that is moderately sloped (slopes ranging from 0.023 to 0.053 feet per foot); the eastern section is much flatter (slopes of 0.011 feet per foot) and industrial activities are prevalent. The Mississippi River defines the eastern boundary of the catchment area, and lies at an elevation of about 295 feet above mean sea level (msl).

The Prairie catchment area is drained by one major trunk sewer varying in size from a three foot by four foot egg-shaped brick sewer to an eight foot diameter sewer. This sewer transports wastewater from the eastern sections of the drainage area to the interceptor tunnel. It runs beneath Prairie Avenue the majority of its length. The Prairie trunk sewer discharges through the interceptor to the municipal treatment plant at Bissell Point (see Figure 4.9). During dry weather conditions (at low river stage when the CSO study was conducted) the sanitary wastewater from the Prairie trunk line is diverted by a one foot high dam structure into a 1.5 foot diameter spur pipe that directs the flow to a gatewell chamber. This flow is then directed to the North Interceptor Tunnel leading to the Bissell Point Treatment Plant. The dam in the Prairie regulator forms a weir at an elevation of 403.2 feet above msl. Combined sewer flows that exceed the hydraulic capacity of the 1.5-ft diameter spur pipe discharge over the weir/dam structure to the Mississippi River, which is approximately 1,500 feet from the weir. River stages above 21.3 feet on the

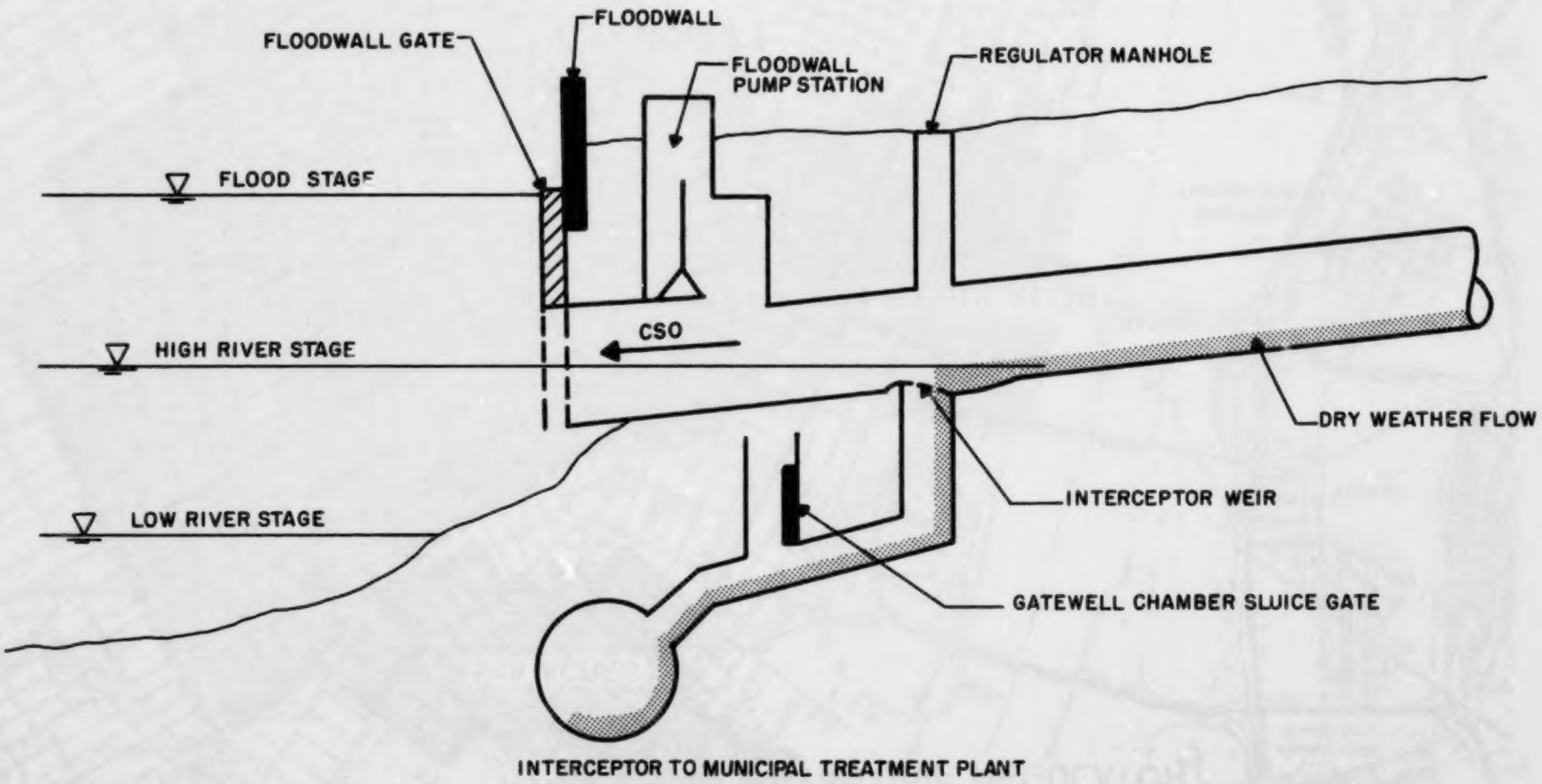
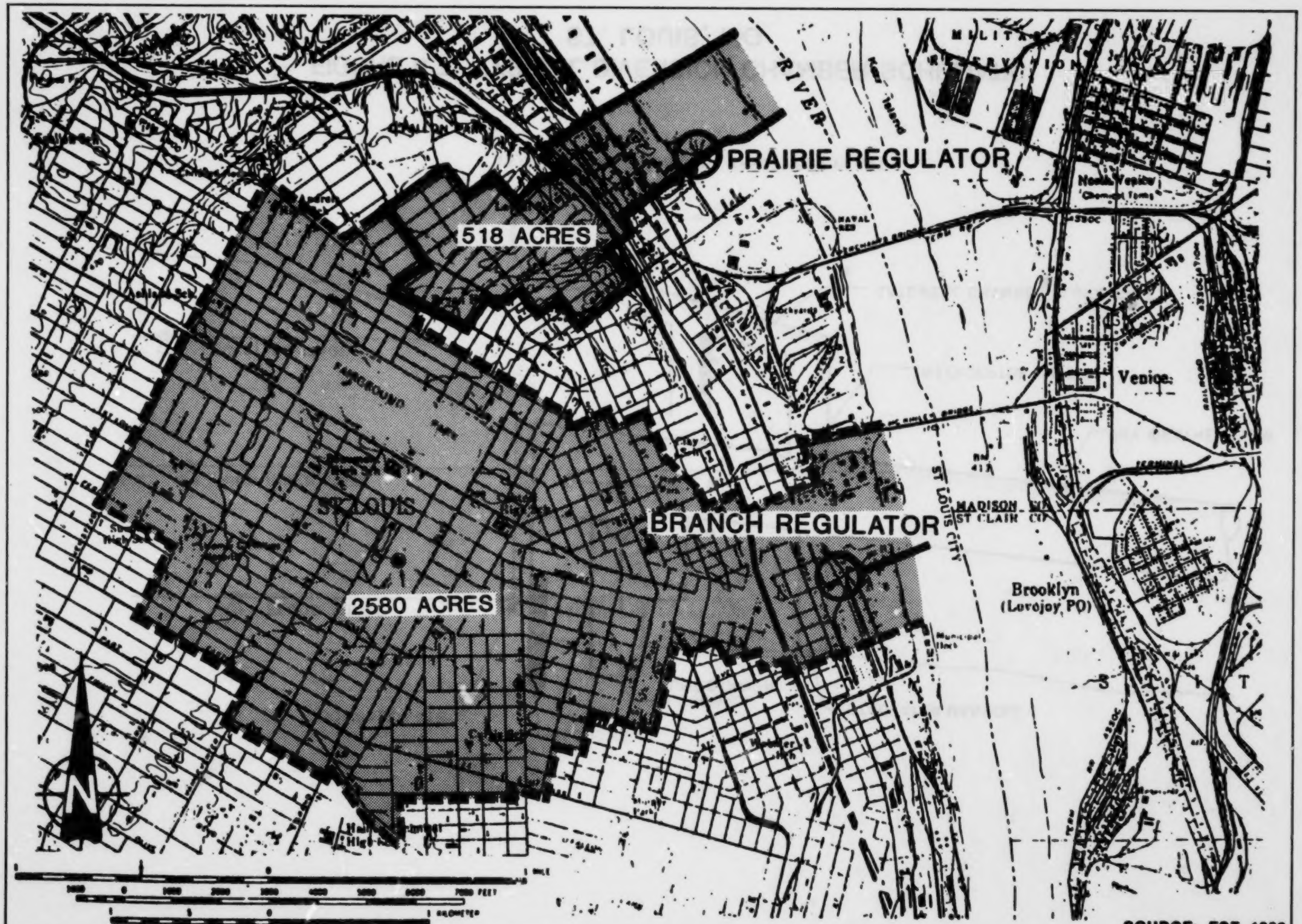

FLOODWALL GATE
FLOODWALL
FLOODWALL PUMP STATION
REGULATOR MANHOLE
FLOOD STAGE
CSO
HIGH RIVER STAGE
DRY WEATHER FLOW
INTERCEPTOR WEIR
LOW RIVER STAGE
GATEWELL CHAMBER SLUICE GATE
INTERCEPTOR TO MUNICIPAL TREATMENT PLANT

FIGURE 4.7 TYPICAL DIVERSION CHAMBER SCHEMATIC
ST. LOUIS, MO


PRAIRIE REGULATOR
518 ACRES
BRANCH REGULATOR
2580 ACRES
RIVER
ST LOUIS CITY
MADISON
ST CLAIR CO
Venice
Brooklyn
(Lovejoy PO)
ST LOUIS
N

SOURCE: ESE, 1982.

FIGURE 4.8 GEOGRAPHICAL LOCATION OF THE PRAIRIE AND BRANCH DRAINAGE AREAS

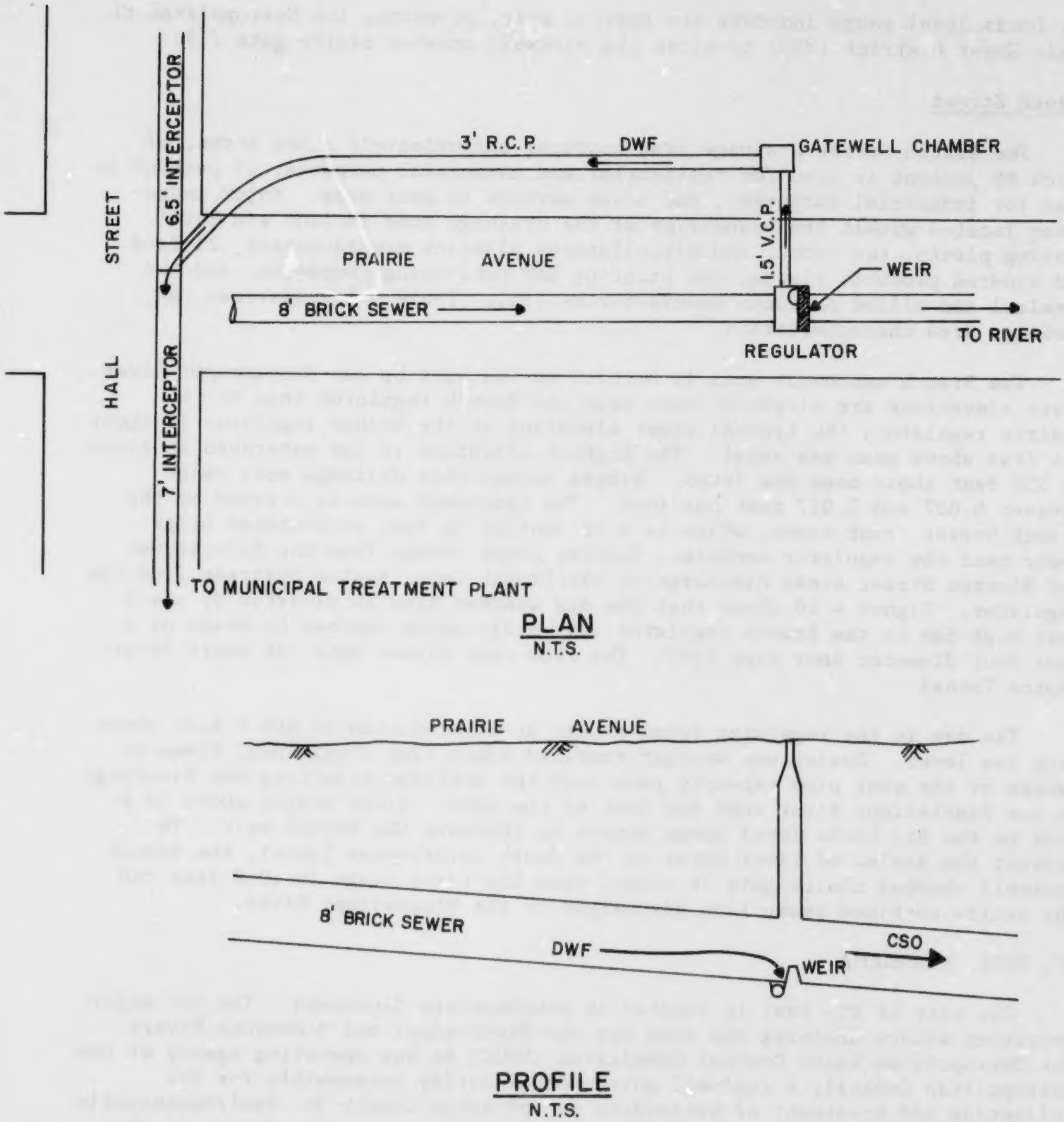

3' R.C.P.
DWF
GATEWELL CHAMBER
6.5' INTERCEPTOR
STREET
1.5' V.C.P.
PRAIRIE
AVENUE
WEIR
8' BRICK SEWER
TO RIVER
REGULATOR
HALL
7' INTERCEPTOR
TO MUNICIPAL TREATMENT PLANT
PLAN
N.T.S.
PRAIRIE
AVENUE
8' BRICK SEWER
DWF
CSO
WEIR
PROFILE
N.T.S.

FIGURE 4.9 PRAIRIE REGULATOR ARRANGEMENT

St. Louis level gauge inundate the Prairie weir, prompting the Metropolitan St. Louis Sewer District (MSD) to close the gatewell chamber sluice gate (19).

Branch Street

The Branch Street drainage area contains approximately 2,580 acres, of which 80 percent is used for residential and commercial purposes, 13 percent is used for industrial purposes , and seven percent is open area. Major industries located within the boundaries of the drainage area include six metal plating plants, two rubber and miscellaneous plastics manufacturers, 21 food and kindred products plants, two printing and publishing companies, and two chemical and allied products manufacturers (20). Table 3.1 summarizes the drainage area characteristics.

The Branch catchment area is bounded on the east by the Mississippi River. River elevations are slightly lower near the Branch regulator than at the Prairie regulator; the typical river elevation at the Branch regulator is about 394 feet above mean sea level. The highest elevation in the watershed is close to 550 feet above mean sea level. Slopes across this drainage area range between 0.007 and 0.017 feet per foot. The catchment area is drained by the Branch Street trunk sewer, which is a 12 foot by 14 foot arch-shaped brick sewer near the regulator manhole. Smaller trunk sewers from the Palm Street and Blanton Street areas discharge to the Branch sewer system upstream from the regulator. Figure 4.10 shows that the dry weather flow is diverted by a 4.8 foot high dam in the Branch regulator into a diversion chamber by means of a four foot diameter spur pipe (19). The flow then passes into the South Interceptor Tunnel.

The dam in the regulator forms a weir at an elevation of 400.8 feet above mean sea level. During wet weather combined sewer flow conditions, flows in excess of the spur pipe capacity pass over the weir/dam structure and discharge to the Mississippi River some 800 feet to the east. River stages above 19.8 feet on the St. Louis level gauge appear to inundate the Branch weir. To prevent the inflow of river water to the South Interceptor Tunnel, the Branch gatewell chamber sluice gate is closed when the river stage is 19.8 feet and the entire combined sewer flow discharges to the Mississippi River.

ST. PAUL, MINNESOTA

The city of St. Paul is located in southeastern Minnesota. The two major receiving waters draining the area are the Mississippi and Minnesota Rivers. The Metropolitan Waste Control Commission (MWCC) is the operating agency of the Metropolitan Council, a regional governmental entity responsible for the collection and treatment of wastewater in the seven-county St. Paul/Minneapolis metropolitan area. The MWCC is responsible for the operation of some of the CSO regulators located within the St. Paul corporate limits (21). The other CSO regulators are the responsibility of the city of St. Paul.

Of the approximately 27,170 acres within the St. Paul city limits, about 21,220 acres, or 78 percent, are served by combined sewers. The average number of overflows from 1970 to 1974 ranged from eight to 28.5 per year per regulator.

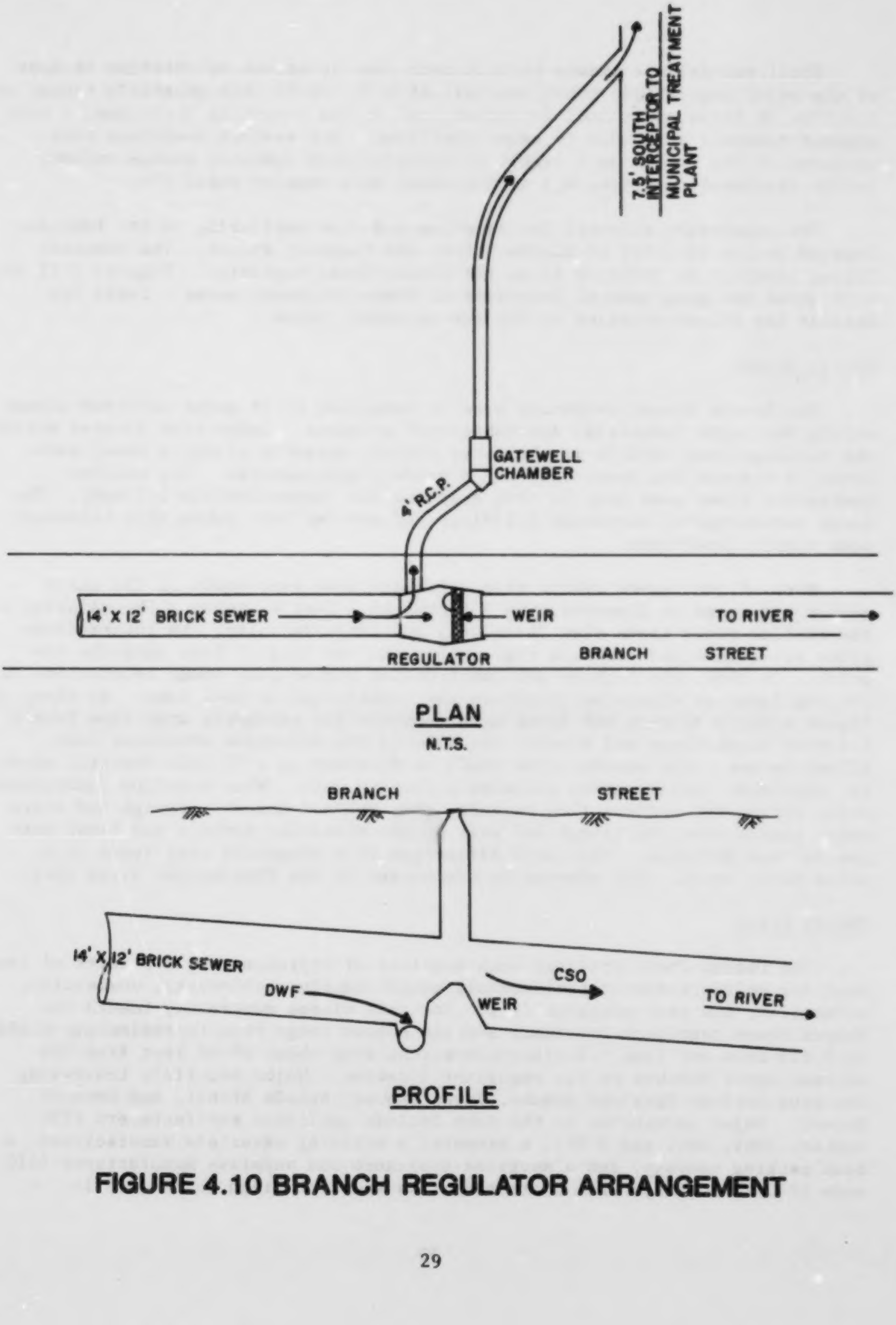

7.5' SOUTH INTERCEPTOR TO MUNICIPAL TREATMENT PLANT
GATEWELL CHAMBER
4' R.C.P.
14' X 12' BRICK SEWER
WEIR
TO RIVER
REGULATOR
BRANCH
STREET
PLAN
N.T.S.
BRANCH
STREET
14' X 12' BRICK SEWER
CSO
DWF
WEIR
TO RIVER
PROFILE

FIGURE 4.10 BRANCH REGULATOR ARRANGEMENT

Total rainfall in excess of 0.10 inch usually causes an overflow at four of the major regulators; total rainfall of 0.20 - 0.30 inch generally causes an overflow at three additional locations; and at the remaining locations, a more intense rainfall is needed to cause overflows. Dry weather overflows have occurred in the system as a result of unanticipated domestic sewage volumes and/or regulator blockage, but do not occur on a regular basis (9).

The regulators selected for sampling and flow monitoring in St. Paul are located in the vicinity of Eustis Street and Fountain Street. The Fountain Street location is referred to as the Phalen Creek regulator. Figures 4.11 and 4.12 shows the geographical locations of these catchment areas. Table 3.1 details the characteristics of the two catchment areas.

Eustis Street

The Eustis Street tributary area is comprised of 78 acres utilized almost solely for light industrial and commercial purposes. Industries located within the drainage area include an abandoned tractor assembly plant, a steel warehouse, a die casting operation, and a battery manufacturer. Dry weather wastewater flows generated in this area are low (approximately 0.1 mgd). The large percentage of warehouse buildings and parking lots makes this catchment area highly impervious.

Most of the sewers within this catchment area were built in the early 1900's and range in diameter from 9 inches to 7 feet 6 inches. The majority of the smaller pipes (less than 24-inches) are vitrified clay; the intermediate sizes are reinforced concrete pipe (RCP); and the large 7-foot conduits are brick. In 1965, the Highway 280 construction forced some sewer relocations and the regulator or diversion structure was constructed at that time. As shown in Figure 4.13, a 60-inch RCP trunk sewer conveys the catchment area flow from a 7.5-foot trunk sewer and directs the flow to the diversion structure near Wabash Avenue. Dry weather flow (DWF) is diverted to a 15-inch domestic sewer; the regulator configuration contains a leaping weir. When overflow conditions occur during wet weather flow periods, the combined domestic sewage and storm water spills over the trough and weir in the diversion manhole and flows into the 54-inch RCP pipe. This pipe discharges to a dropshaft that leads to a storm water tunnel that eventually discharges to the Mississippi River (21).

Phalen Creek

The Phalen Creek drainage area consists of approximately 870 acres of land used for multiple-family residential, single family residential, commercial, industrial, and park purposes (22). The area slopes moderately toward the Phalen Creek regulator location; average slopes range from approximately 0.005 to 0.016 feet per foot. Surface elevations drop about 60-80 feet from the highest upper reaches to the regulator location. Major arterials traversing the area include Maryland Avenue, Payne Avenue, Arcade Street, and Seventh Street. Major industries in the area include appliance manufacturers (SIC numbers 3585, 3632 and 3635), a brewery, a building materials manufacturer, a meat packing company, and a surgical appliance and supplies manufacturer (SIC code 3842). Drainage area characteristics are summarized in Table 3.1.

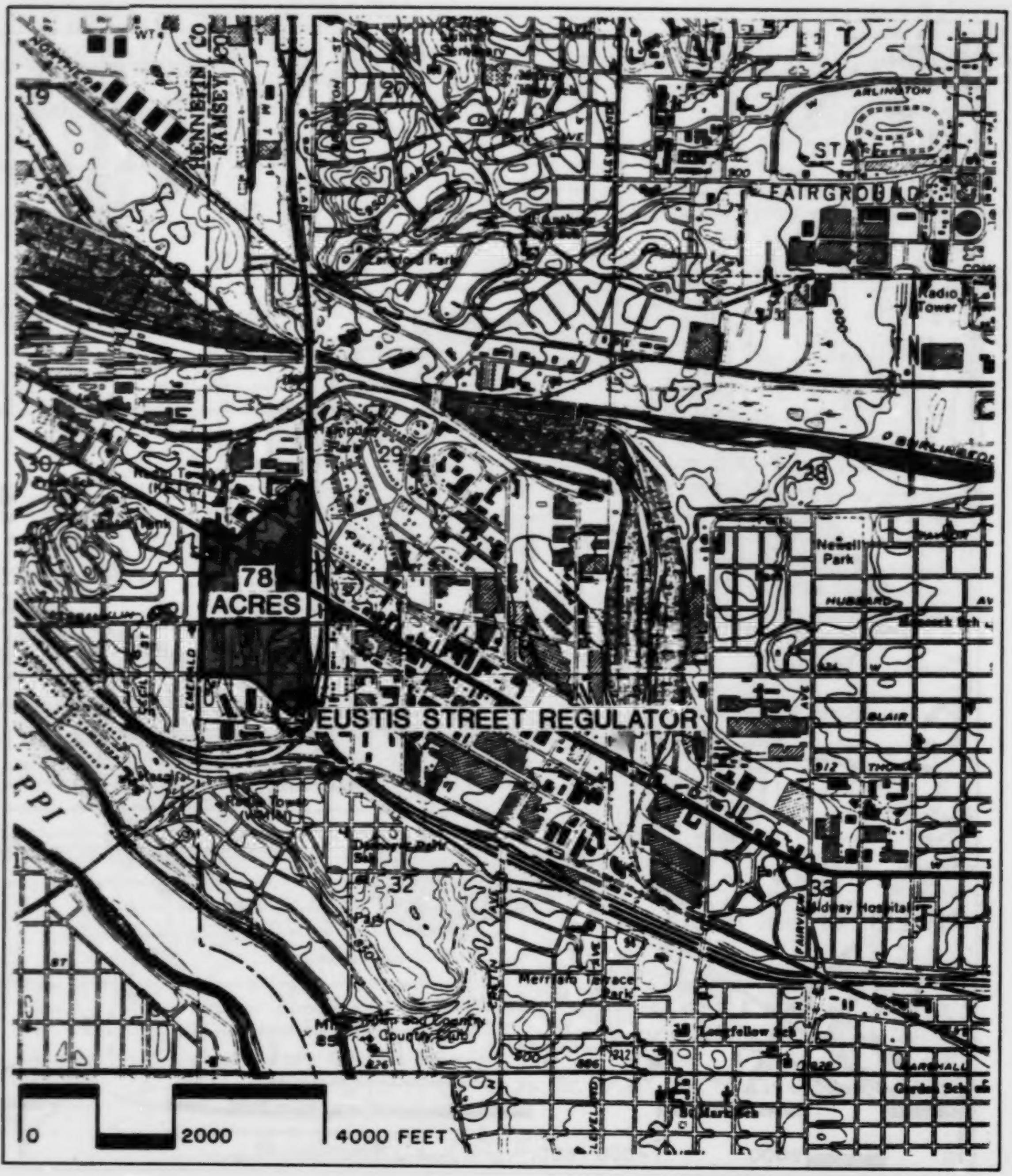

78
ACRES
EUSTIS STREET REGULATOR
HENNEPIN CO
RAMSEY CO
STATE
FAIRGROUNDS
Radio
Tower
Newell
Park
Midway Hospital
Merriam Terrace
Park
Longfellow Sch
0
2000
4000 FEET

FIGURE 4.11 GEOGRAPHICAL LOCATION OF EUSTIS STREET DRAINAGE AREA

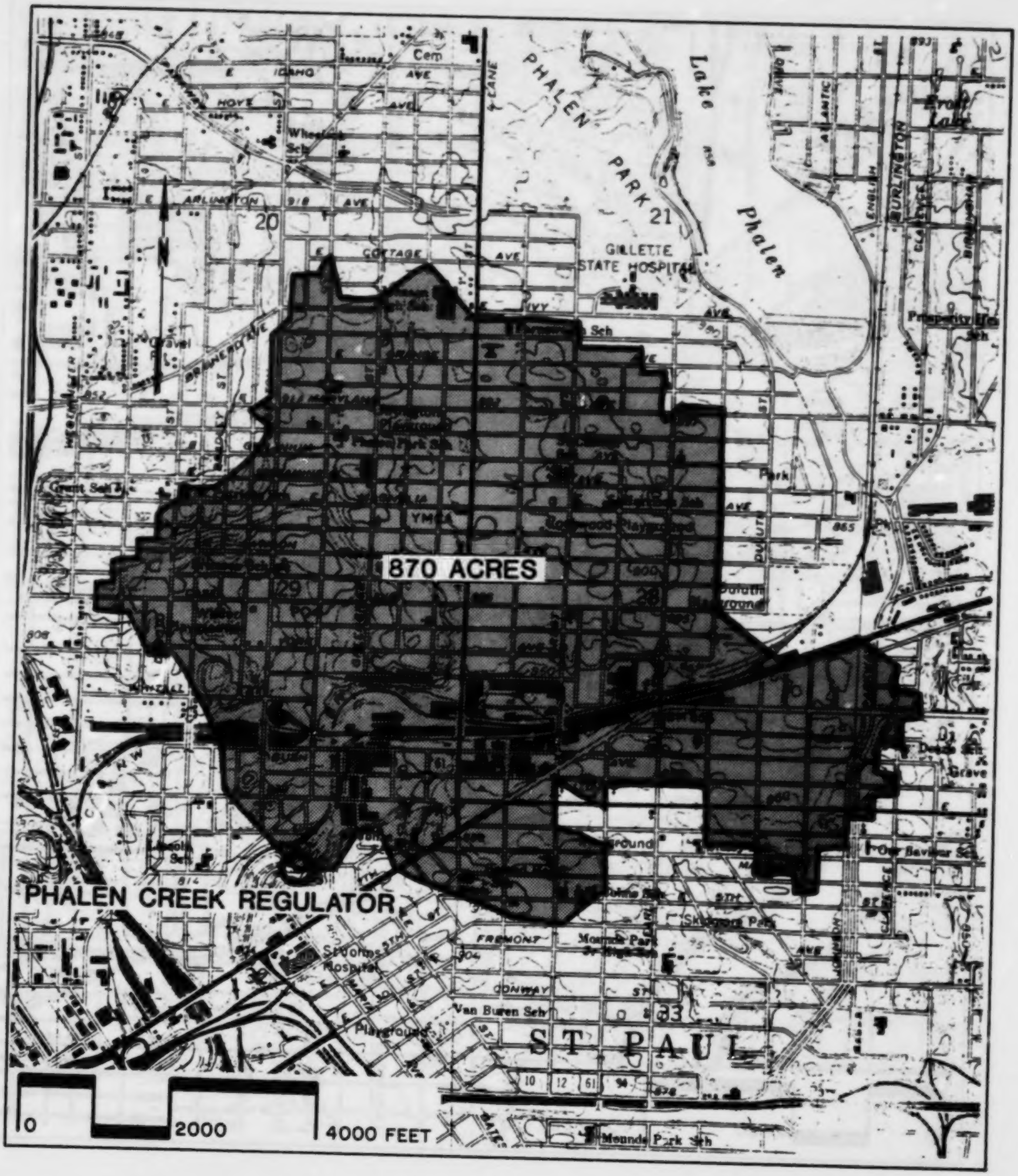

PHALEN PARK
Lake Phalen
GILLETTE STATE HOSPITAL
870 ACRES
PHALEN CREEK REGULATOR
ST PAUL
0
2000
4000 FEET

FIGURE 4.12 GEOGRAPHICAL LOCATION OF PHALEN CREEK DRAINAGE AREA

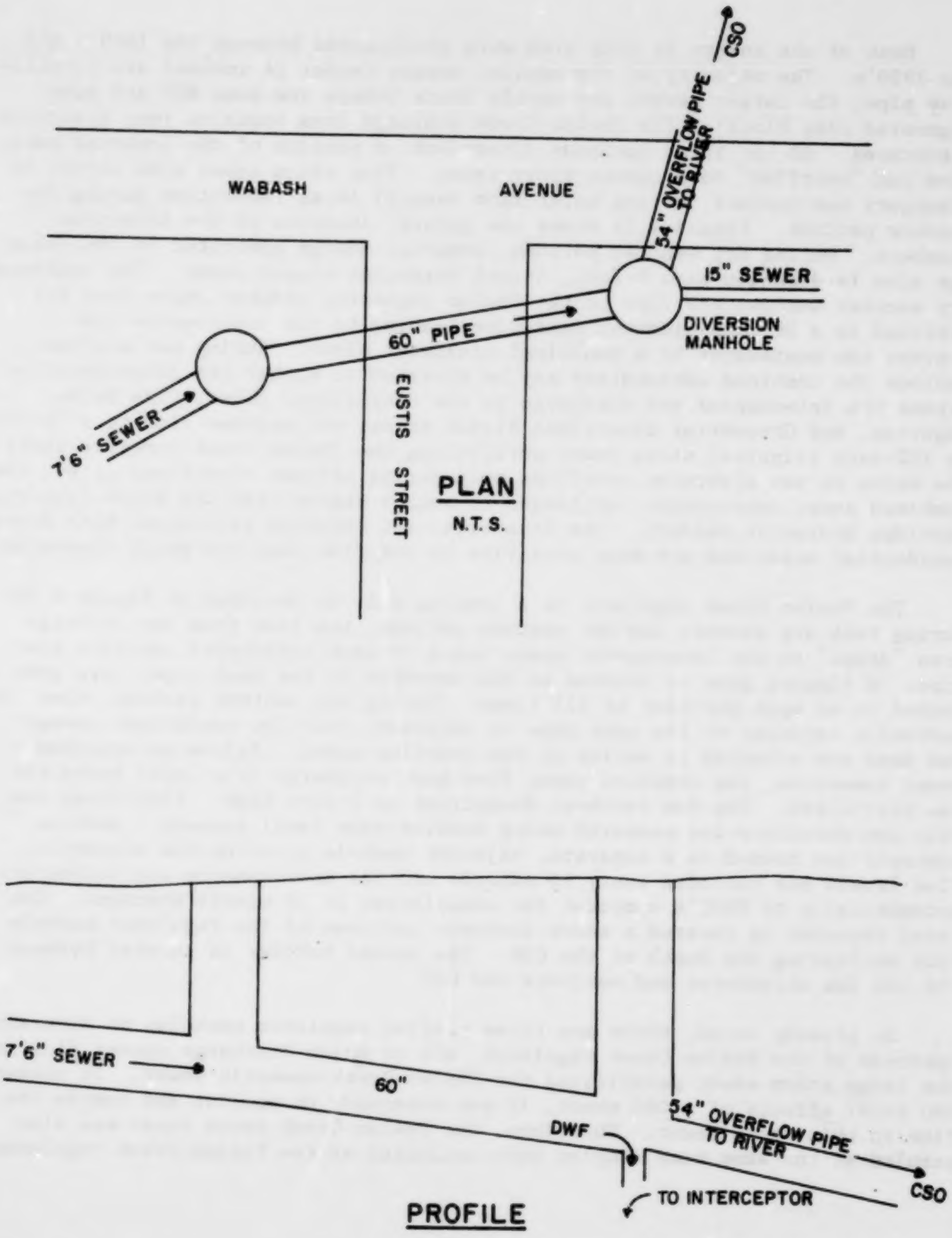

CSO
54" OVERFLOW PIPE TO RIVER
WABASH
AVENUE
15" SEWER
DIVERSION MANHOLE
60" PIPE
7'6" SEWER
EUSTIS STREET
PLAN
N.T.S.
7'6" SEWER
60"
54" OVERFLOW PIPE TO RIVER
DWF
TO INTERCEPTOR
CSO
PROFILE

FIGURE 4.13 EUSTIS STREET REGULATOR ARRANGEMENT

Most of the sewers in this area were constructed between the 1890's and the 1920's. The majority of the smaller sewers (under 24 inches) are vitrified clay pipe; the larger sewers are mostly brick (there are some RCP and some segmented clay block). The Phalen Creek drainage area contains four diversion structures. At the three upstream diversions, a portion of the combined sewer flow can "overflow" to a common storm sewer. This storm sewer also serves to transport non-contact cooling water from several local industries during dry weather periods. Figure 4.14 shows the general location of the diversion chambers. During dry weather periods, domestic sewage generated in the drainage area is directed to a 9-foot, 4-inch horseshoe-shaped sewer. The combined dry weather wastewaters flow to the Phalen regulator chamber where they are diverted to a 30-inch diameter spur pipe leading to the interceptor that conveys the wastewater to a municipal treatment plant. During wet weather periods the combined wastewaters may be diverted to either the interceptor or bypass the interceptor and discharge to the Mississippi River. The Weide, Edgerton, and Greenbriar diversions direct excess wet weather flow to a 72-inch by 102-inch eliptical storm sewer paralleling the Phalen Creek domestic sewer. The Weide Street diversion overflows only during extreme conditions (i.e., the combined sewer interceptor surcharges to such a degree that the Weide diversion provides hydraulic relief). The Greenbriar and Edgerton diversions both drain residential areas and are more sensitive to overflow than the Weide diversion.

The Phalen Creek regulator is a leaping weir as detailed in Figure 4.15. During both dry weather and wet weather periods, the flow from the drainage area "drops" to the interceptor sewer via a 30-inch reinforced concrete spur pipe. A tipping gate is located at the entrance to the spur pipe; this gate is locked in an open position at all times. During wet weather periods, when the hydraulic capacity of the spur pipe is exceeded, overflow conditions prevail. Two dams are situated in series on the overflow sewer. Before an overflow event commences, the combined sewer flow must surcharge to a level above the dam structures. The dam farthest downstream is 2-feet high. Flow rates over this dam structure are measured using bubbler-type level sensors. Bubbler controls are housed in a separate, adjacent manhole noted on the schematic. Flow levels are recorded every 15 seconds and the measurements are telemetered automatically to MWCC's computer for compilation of 15 minute averages. One level recorder is located a short distance upstream of the regulator manhole thus monitoring the depth of the CSF. The second bubbler is located between the two dam structures and monitors the CSO.

As already noted, there are three smaller regulator manholes or diversions upstream of the Phalen Creek regulator, all of which discharge excess flow into the large storm sewer paralleling the Phalen Creek domestic sewer. To assess the total effects of a CSO event, it was necessary to monitor and sample the flow in this storm sewer. Therefore, the Phalen Creek storm sewer was also sampled at the same time samples were collected at the Phalen Creek regulator.

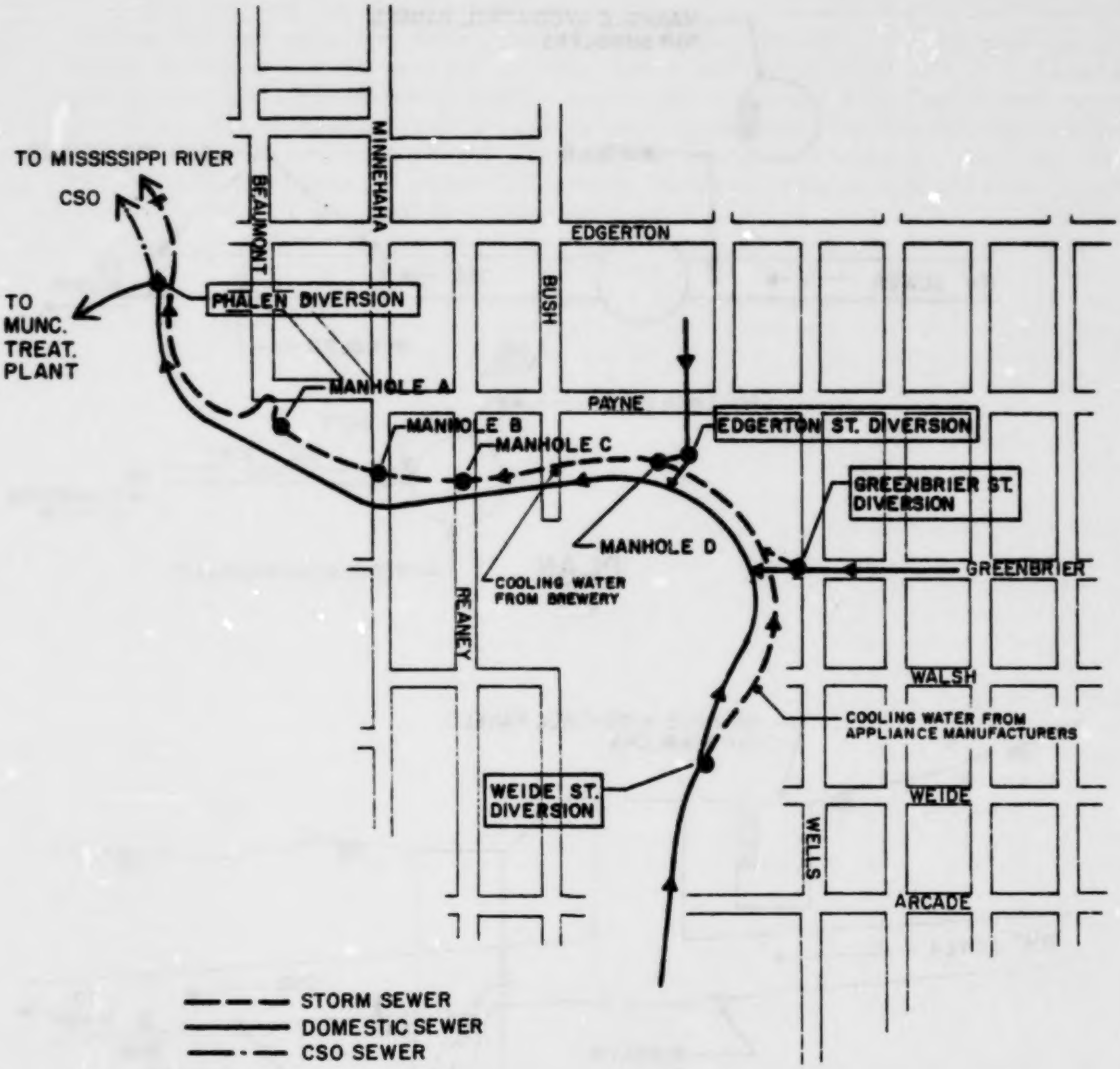

TO MISSISSIPPI RIVER
CSO
TO MUNC. TREAT. PLANT
PHALEN DIVERSION
MANHOLE A
MANHOLE B
MANHOLE C
MANHOLE D
EDGERTON ST. DIVERSION
GREENBRIER ST. DIVERSION
COOLING WATER FROM BREWERY
COOLING WATER FROM APPLIANCE MANUFACTURERS
WEIDE ST. DIVERSION
BEAUMONT
MINNEHAHA
BUSH
EDGERTON
PAYNE
REANEY
GREENBRIER
WALSH
WEIDE
WELLS
ARCADE
STORM SEWER
DOMESTIC SEWER
CSO SEWER

FIGURE 4.14 LOCATION OF THE PHALEN CREEK DIVERSION STRUCTURES

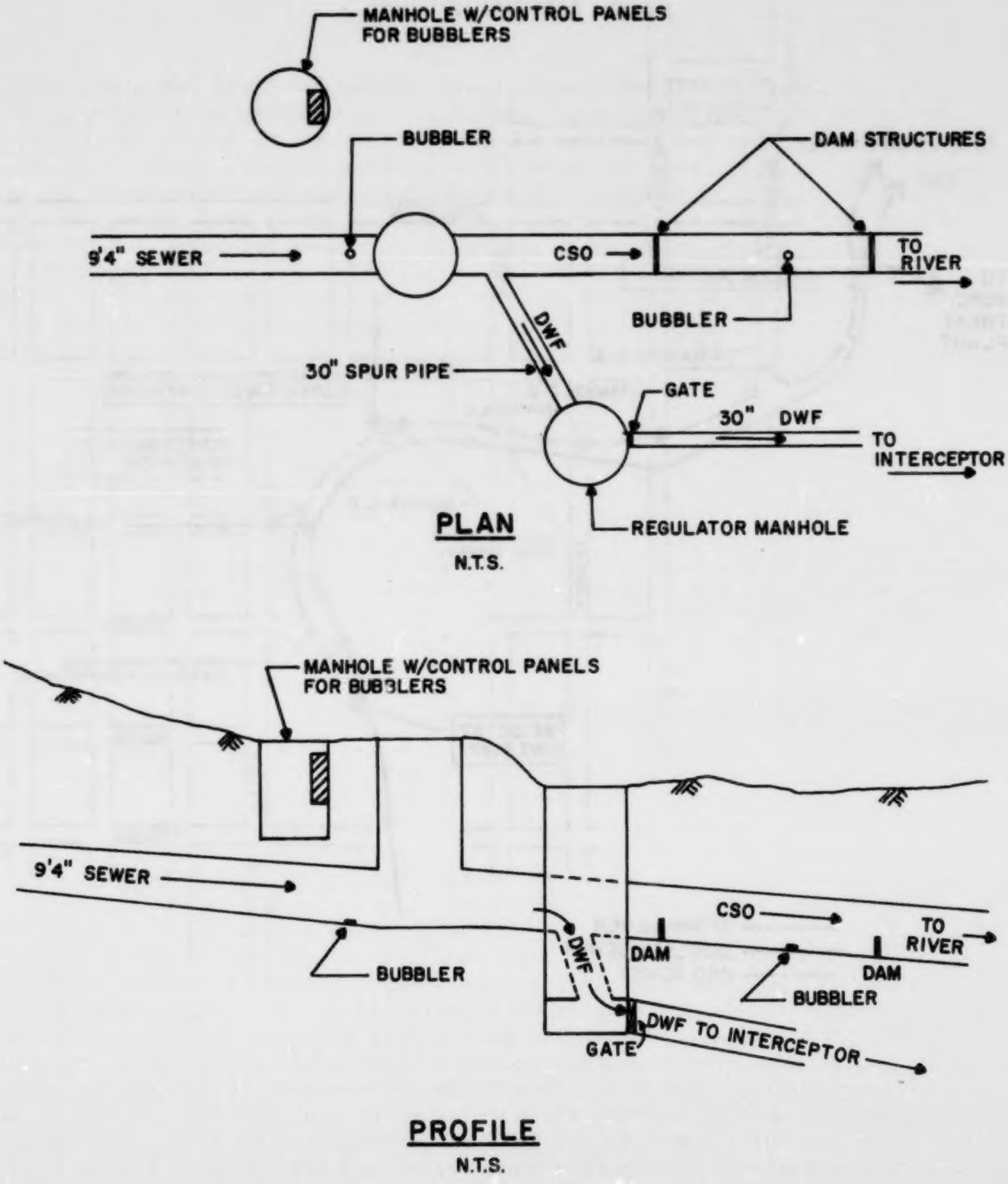

MANHOLE W/CONTROL PANELS FOR BUBBLERS
BUBBLER
DAM STRUCTURES
9'4" SEWER
CSO
TO RIVER
BUBBLER
DWF
30" SPUR PIPE
GATE
30" DWF
TO INTERCEPTOR
REGULATOR MANHOLE
PLAN
N.T.S.
MANHOLE W/CONTROL PANELS FOR BUBBLERS
9'4" SEWER
CSO
TO RIVER
DWF
DAM
DAM
BUBBLER
BUBBLER
GATE
DWF TO INTERCEPTOR
PROFILE
N.T.S.

FIGURE 4.15 PHALEN CREEK REGULATOR ARRANGEMENT

SECTION 5

SAMPLING PROGRAM

As previously mentioned, the purposes of the CSO toxic pollutant study are to determine the occurrence, mass, and source of priority toxic pollutants in combined sewer flows and combined sewer overflows and to review the relationship of the pollutant mass in these flows to urban runoff, storm intensity, land use, and other parameters. To accomplish these objectives, the characteristics of dry and wet weather flows and sewer sediments were documented. Sample locations were selected so that pollutant mass balances within each of the study catchment areas could be estimated. The mass balance approach identifies definite sources and discharge patterns of pollutants. In addition, samples were collected to assess the character and fate of any observed first flush (i.e., is the first flush wastewater contained and discharged to a POTW or discharged as CSO) (14).

As described in Section 4, eight catchment areas were selected for monitoring and sampling. Each drainage area was monitored during a 24-hour dry weather period to establish daily pollutant masses (i.e., background samples) void of wet weather influences. Wet weather samples were collected during three separate storm events per location with the exception of the Eustis Street and Phalen Creek drainage areas in St. Paul. These areas were monitoried during two storm events. A total of 135 wastewater samples were collected and analyzed for the selected conventional and nonconventional pollutants and for the priority toxic pollutants listed on Table 5.1.

SAMPLING METHODOLOGIES

A rigid sampling protocol, detailed in a sampling and logistics plan prepared for each site, was followed throughout this study to assure consistency in sampling techniques for each of the eight drainage areas. Depending on the sample location, samples of the wastewater were procured either as grab samples to provide an instantaneous characterization of the wastewater or as composite samples that represent an overall wastewater characterization for the duration of the sample period.

The typical wastewater flow pattern for this study encompassed large variations in the flow during a relatively short duration. For this reason, the majority of composite samples were collected as flow proportioned samples. In these instances, aliquot samples were collected based on the flow volume in one of two manners: (1) constant volume aliquots were collected at varying time intervals (e.g., a 500 ml aliquot was collected at 50,000 gallon intervals regardless of the time between aliquots); or (2) constant time intervals were determined and the aliquot volume was proportional to the flow. The latter of these two methods was used most frequently during this study. Figure 5.1 presents an example of the flow proportion compositing technique.

Occasionally composites were collected as constant time-constant volume (ct-cv) samples. In these situations a fixed aliquot volume was collected at a

TABLE 5.1 POLLUTANTS ANALYZED FOR DURING CSO STUDY

I. CONVENTIONAL/NONCONVENTIONAL POLLUTANTS

- biochemical oxygen demand (5-day)
- chemical oxygen demand
- total organic carbon
- total solids
- total volatile solids
- total volatile suspended solids
- total suspended solids
- total volatile dissolved solids
- total dissolved solids
- settleable solids
- chloride
- ammonia as nitrogen
- total phenols
- oil and grease

- aluminum
- barium
- boron
- calcium
- cobolt
- iron
- magnesium
- manganese
- molybdenum
- sodium
- tin
- titanium
- vanadium
- yttrium

II. PRIORITY TOXIC POLLUTANTS

Volatile Organics

- bromodichloromethane
- carbon tetrachloride
- bromoform
- chloroform
- toluene
- dibromochloromethane
- acrolein
- acrylonitrile
- benzene
- chlorobenzene
- chloroethane
- ethylbenzene
- bromomethane
- chloromethane
- methylene chloride
- tetrachloroethene
- trichorofluoromethane
- 1,1-dichloroethane
- 1,1-dichloroethene
- 1,1,2-trichloroethane
- 1,1,2,2-tetrachloroethane
- 1,2-dichloroethane
- 1,2-dichloropropane
- trans-1,2-dichloroethene
- 1,3-dichloropropene
- 2-chloroethylvinyl ether
- dichlorodifluoromethane
- vinyl chloride
- trichloroethene

Semi-Volatile Acid

- 4-chloro-3-methylphenol
- 2-chlorophenol
- 2-nitrophenol
- 2,4-dichlorophenol
- 2,4-dimethylphenol
- 2,4-dinitrophenol
- 2,4,6-trichlorophenol
- 4-nitrophenol
- 2-methyl-4,6-dinitrophenol
- phenol
- pentachlorophenol

Semi-Volatile Base/Neutrals

- acenaphthylene
- acenaphthene
- anthracene
- benzo(b)fluoranthene
- benzo(k)fluoranthene
- benzo(a)pyrene
- bis(2-chloroethoxy)methane
- bis(2-chloroisopropyl)ether
- butyl benzyl phthalate
- chrysene
- diethylphthalate
- dimethylphthalate
- 1,2-diphenylhydrazine
- fluoranthene
- fluorene
- hexachlorocyclopentadiene
- hexachlorobutadiene
- hexachloroethane
- indeno(1,2,3-cd)pyrene
- isophorone
- n-nitrosodi-n-propylamine
- n-nitrosodiphenylamine
- n-nitrosodimethylamine
- nitrobenzene
- phenanthrene
- pyrene
- benzo(ghi)perylene
- benzo(a)anthracene
- 1,2-dichlorobenzene
- 1,2,4-trichlorobenzene
- dibenzo(a,h)anthracene
- 1,3-dichlorobenzene
- 1,4-dichlorobenzene
- 2-chloronaphthalene
- di-n-octyl phthalate
- 2,4-dinitrotoluene
- 2,6-dinitrotoluene
- 3,3-dichlorobenzidine
- 4-bromophenyl phenyl ether
- 4-chlorophenyl phenyl ether
- 2,3,7,8-tetrachlorodibenzo-p-dioxin
- naphthalene
- bis(2-ethylhexyl)phthalate
- di-n-butyl phthalate
- benzidine
- hexachlorobenzene

Pesticide and PCBs

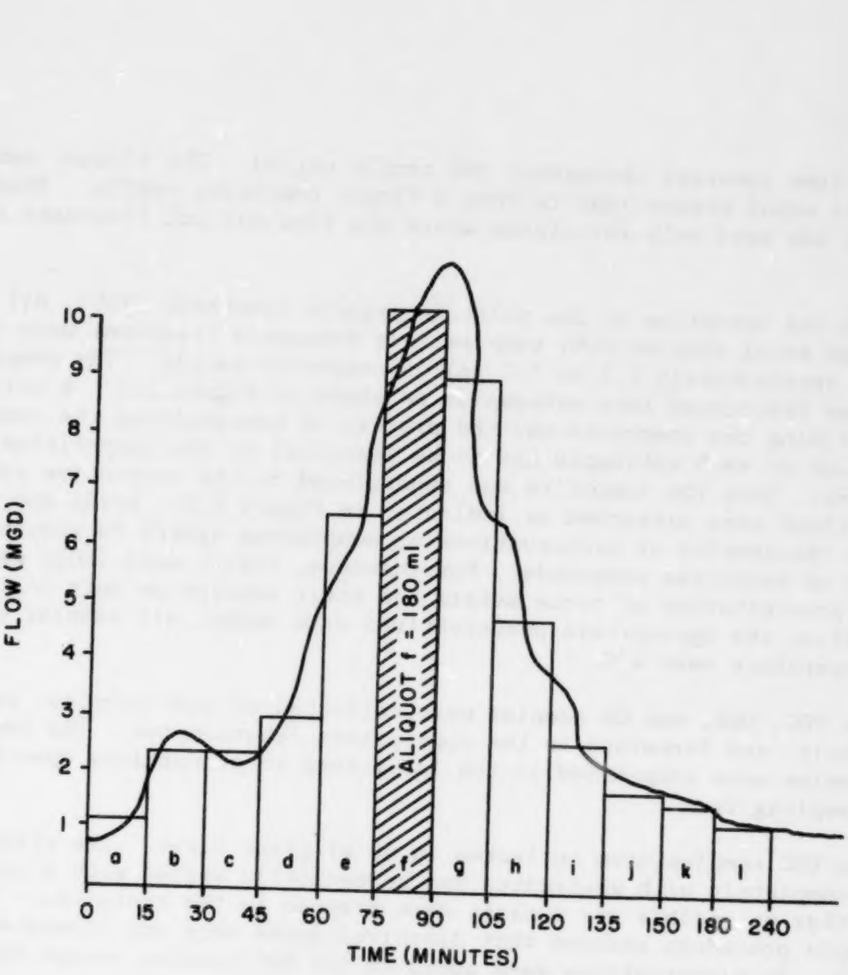
- endosulfan sulfate
- a-endosulfan
- b-endosulfan
- endrin aldehyde
- 4,4-ddt
- 4,4-ddd
- 4,4 dde
- aldrin
- a-bhc
- b-bhc
- d-bhc
- g-bhc
- chlordane
- dieldrin
- endrin
- toxaphene
- heptachlor
- heptachlor epoxide
- pcb-1016
- pcb-1221
- pcb-1232
- pcb-1242
- pcb-1248
- pcb-1254
- pcb-1260

Metals

- antimony
- arsenic
- beryllium
- cadmium
- chromium
- copper
- lead
- mercury
- nickel
- selenium
- silver
- thallium
- zinc

Others

- cyanide



$$\text{REQUIRED COMPOSITE VOLUME (RCV)} = 11{,}350\text{ ml} = \Sigma\,\text{(SAMPLE ALIQUOTS)}$$

$$= \text{ALIQUOT } a + \text{ALIQUOT } b + \ldots\ldots\ldots + \text{ALIQUOT } l$$

$$\text{VOLUME OF ALIQUOT } f = \left\{\frac{\text{(AVE. FLOW RATE DURING INTERVAL } f\text{)(15 MINUTES)}}{\text{(TOTAL VOLUME FROM STORM HYDROGRAPH)}}\right\}\left\{\begin{matrix}\text{REQUIRED}\\ \text{COMPOSITE}\\ \text{VOLUME}\end{matrix}\right\}$$

$$= \left\{\frac{\text{(10.4 MGD)(15 MINUTE)}}{\text{(6.84 MG)}\ \left(1{,}440\,\frac{\text{MINUTES}}{\text{DAY}}\right)}\right\}\left\{11{,}350\text{ ml}\right\} = 180\text{ ml}$$

FIGURE 5.1 FLOW PROPORTIONING EXAMPLE

constant time interval throughout the sample period. The aliquot samples were blended in equal proportions to form a single composite sample. This composite technique was used only for storms where the flow did not fluctuate significantly.

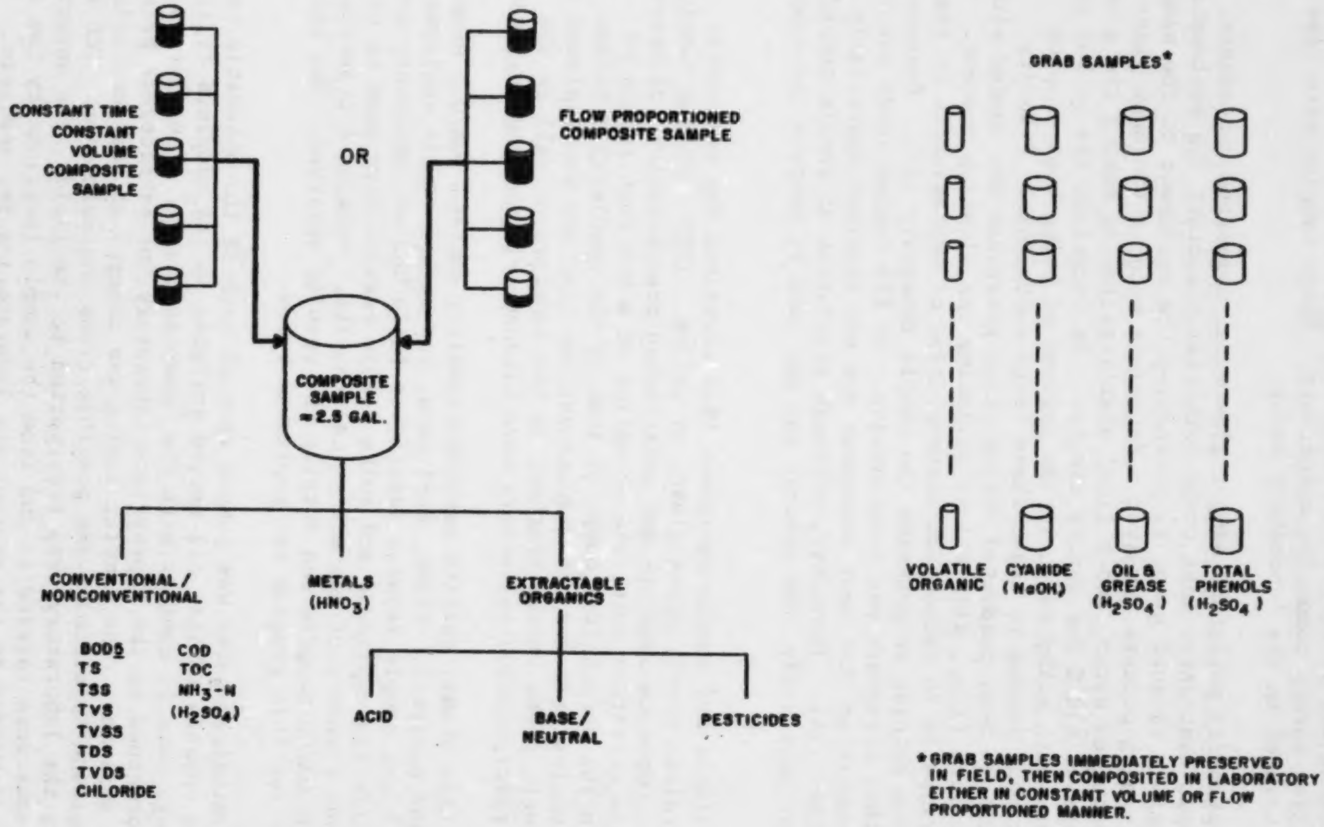
With the exception of the volatile organic compounds (VOC), oil and grease (O&G), and total cyanide (CN) samples, all subsample fractions were extracted from the approximately 2.5 to 3.0 gallon composite sample. The composite sample was fractioned into subsamples as shown in Figure 5.2. A critical step in fractioning the composite was the process of homogenizing the sample. The composition of each subsample had to be identical to the composition of other subsamples. Once the composite was apportioned to the respective subsamples, the fractions were preserved as indicated in Figure 5.2. Acids and bases were added to the samples as preservatives or complexing agents to stop biological activity or stabilize compounds. For instance, nitric acid (NO_3) was used to prevent precipitation of trace metals and their adsorption onto container walls (23). After the appropriate preservatives were added, all samples were chilled to a temperature near 4°C.

The VOC, O&G, and CN samples were collected as grab samples, preserved immediately, and forwarded to the appropriate laboratories. The individual grab samples were composited in the laboratory in proportions specified by the field sampling team.

The VOC samples were collected in 40 ml glass vials. The vials were filled completely with wastewater and hermetically sealed with a teflon-lined cap so that no visible air pockets were trapped in the container. This vigorous sample procedure ensured that dissolved gases were not liberated from solution. No preservatives were added to the VOC samples except the tap water VOC samples. Sodium thiosulfate was added to these samples to neutralize the residual chlorine present. All VOC samples were chilled and then forwarded to the laboratory.

Cyanide samples were collected in amber plastic containers and preserved with sodium hydroxide (NaOH) because of the reactive and unstable characteristics of most cyanides. NaOH was added to prevent the loss of volatile compounds by forming a salt complexing compound; the amber bottle protected the sample from exposure to direct sunlight which can cause rapid photolysis (24).

Oil and grease samples were collected in wide-mouth glass containers and acidified with sulfuric acid (H_2SO_4). Individual samples were analyzed (rather than compositing the samples) to eliminate losses of grease that may adhere to the laboratory equipment and sample containers. Because of the substantial number of analysis that were required to obtain average O&G concentrations during the storm events, the sampling interval for this parameter was modified. At a maximum, six O&G samples per location were taken during a single storm event. These samples were normally collected during the initial portion of the storm and were collected directly from the wastewater instead of being collected by an intermediate vessel. In general, the O&G values should be viewed as biased upward since they usually represent the wastewater quality during the initial period of the storm event.


CONSTANT TIME
CONSTANT
VOLUME
COMPOSITE
SAMPLE
OR
FLOW PROPORTIONED
COMPOSITE SAMPLE
COMPOSITE
SAMPLE
≈2.5 GAL.
CONVENTIONAL /
NONCONVENTIONAL
BOD5
TS
TSS
TVS
TVSS
TDS
TVDS
CHLORIDE
COD
TOC
NH3-N
(H2SO4)
METALS
(HNO3)
EXTRACTABLE
ORGANICS
ACID
BASE/
NEUTRAL
PESTICIDES
GRAB SAMPLES*
VOLATILE
ORGANIC
CYANIDE
(NaOH)
OIL &
GREASE
(H2SO4)
TOTAL
PHENOLS
(H2SO4)

*GRAB SAMPLES IMMEDIATELY PRESERVED IN FIELD, THEN COMPOSITED IN LABORATORY EITHER IN CONSTANT VOLUME OR FLOW PROPORTIONED MANNER.

**ALL SAMPLES WERE CHILLED TO 4°C
( ) CHEMICALS IN PARENTHESIS ARE SAMPLE PRESERVATIVES

FIGURE 5.2 SAMPLE COMPOSITING SCHEME**

Samples that were analyzed for the base/neutral (two liters), acid extractable (one liter), and pesticide (one liter) fractions were taken from the 2.5 to 5 gallon glass carboy composite containers. These samples were also chilled and then shipped to the laboratory daily.

All organic priority pollutant sample glassware, composite containers, and miscellaneous sample containers that could potentially contact the wastewater sample were thoroughly cleaned prior to forwarding the equipment to the sample location. The cleaning process involved a detergent bath, a thorough rinse with ultrapure deionized water, and a final sterilization by baking the glassware and containers at 450°C for thirty minutes. On occasions the carboy containers were rinsed with methylene chloride instead of being heat treated because heat treatment tended to break these large containers. Priority pollutant studies have been conducted during which glassware was coated with dichlorodimethylsilane (i.e., silylation) following the cleaning process. The purpose of this rinse is to reduce the accummulation of contaminants on the glass surface, thus helping to preserve the sample integrity (25). Documentation to support this procedure was inconclusive. An EPA funded study concluded "It has been demonstrated that most compounds are not absorbed appreciably by the container walls" (26). Therefore, although silylation of sample containers was considered for this study, the process was not used to prepare the sample containers.

Sample containers and sample equipment that contacted the wastewater samples were stainless steel, pyrex glass, or teflon. ISCO 1580 and Manning S-3000 automatic composite samplers and constructed precipitation collectors all fulfilled this criterion (with the exception of a two-foot length of silicon tubing in the peristaltic pumps of some of the samplers). Teflon tubing was used exclusively for the sampler suction line and was replaced after each sampling event; glass vacuum chambers in the samplers as well as the stainless steel precipitation collectors were cleaned between sampling events.

Throughout this study, quality assurance/quality control (QA/QC) samples were collected and analyzed. Blank, duplicate, and spiked sample analyses were performed. The blank sample results identified field and/or laboratory cross contamination while the duplicate and spike sample results were used to calculate precision and accuracy of the analytical results. Section 6 presents a discussion of the QA/QC program and details the results observed. The QA/QC field procedures for this program are explained below.

Ultrapure deionized water was pumped through each of the automatic samplers before each episode so that all wetted surfaces in the samplers (silicon and teflon tubing) came in contact with the "sampler blank." Four liters were collected and forwarded to the appropriate laboratory for extractable priority toxic pollutant analyses. The sampler tubing was changed at the conclusion of each sampling episode to minimize any possible cross contamination. VOC blanks were prepared in the laboratory then transported to the field. The hermetically sealed blanks were carried to and from the sample locations by the field crews, and then forwarded to the appropriate laboratories for analysis.

Precision and accuracy samples (i.e., duplicate samples) were collected such that a 15 percent QA/QC level was maintained (for each 100 wastewater samples, 15 duplicate analysis were conducted). Sample locations and sample periods were randomly selected for the QA/QC samples. The volumes for the extractable organics and VOC samples at the selected sample locations were doubled during these periods so that the laboratory could run duplicate and spiked analysis.

Dry Weather Background Sampling

Twenty-four Hour Composite Samples--

A single composite sample per catchment area was collected during a 24-hour dry weather period to determine approximate daily dry weather flow volumes and associated pollutant mass. The composite samples were collected at the regulator locations prior to the discharge of the wastewater to the interceptor sewers that conveyed the wastewater to the municipal treatment plant. These samples were used to characterize the dry weather wastewater flow for the respective catchment areas. Sample periods were selected during the middle of the work week (Tuesday, Wednesday, or Thursday) to capture discharges from a cross section of different industrial processes. An extended antecedent dry weather period was desired. Sample locations were situated such that well-mixed representative samples and reliable flow information were obtainable.

Automatic samplers were used whenever the sampling conditions allowed. With the exception of flow proportioned samples collected in Seattle (Lander and Michigan regulator locations), the remaining background samples, whether procured manually or automatically, are constant time-constant volume composites. At the completion of the sample episode the composite samples were homogenized, separated into subsamples (as shown in Figure 5.2), and preserved. VOC, O&G, and CN grab samples were collected at four hour intervals and preserved immediately. The composite subsamples and the six series of individual grab samples were forwarded to the appropriate laboratories via overnight delivery service to minimize the holding time between sample collection and analysis.

Pre-Storm Background Samples--

A grab sample void of urban runoff was collected at the regulator locations immediately prior to the start of each storm event. These samples were used to characterize dry weather pollutant contributions for a storm event. The pre-storm background samples (wet weather background) do not reflect changes in the baseline pollutant mass as a result of industrial discharge variations during the storm event. However, for short duration storm events, the pollutant mass at the beginning of the storm event is viewed as being more representative of the dry weather pollutant contribution during the sampling period than the dry weather composite background samples that were collected weeks or even months prior to the storm event. All pre-storm background samples were collected, preserved, and placed on ice for shipment to the laboratories at the conclusion of the storm event.

Sediment Samples--

Solids deposited in a combined sewer system during dry weather periods may be a source of pollutants in the first flush period during a storm event. For this reason, sediment samples were collected after a minimum seven day dry weather antecedent period to characterize material that may be resuspended and discharged from the collection system during storm periods. Samples were collected as close to the regulator locations as possible (where sediments from the entire drainage area could potentially accumulate).

Collection of sediment samples proved to be more difficult than orginally perceived. Ideally, sediment samples should be obtained by first constructing a temporary dam structure to divert the flow from a segment of sewer; a sample can then be obtained of the "scum sediment" layer along the normally wetted perimeter of the sewer. However, to interrupt the flow and enter a manhole to access a sewer line upstream or downstream of the regulator was difficult, if not impossible. Consequently, five of the six sediment samples collected were from active sewer lines and for the most part, were collected within the confines of a manhole. Only by repeated inspections of manholes could adequate volumes of sediment be collected. The one exception to this was a sediment sample collected from an interceptor line in Providence, RI.

Samples were collected by scraping the bottom of the manhole with a stainless steel beaker. If, as was usually the case, the deposition volume from one location was insufficient for the complete spectrum of analysis, the deposition from the first location was blended with the deposition from other locations to construct a complete composite sample. Samples included two-40 ml VOC samples, a 250 ml CN sample, a one liter metals sample, and a one liter extractable organics sample. A total of six sediment samples were collected and analyzed only for priority toxic pollutants.

No sediment samples were collected from either the Branch or Prairie collection systems in St. Louis due to the lack of any accessible sediments and the imminent dangers involved in entering these sewers. Sediment samples were collected in sewers tributary to the Eustis, Phalen, Michigan, Lander, and Ernest @ Allens drainage areas. In addition, a series of samples were taken from an interceptor line in Providence, Rhode Island, which serves the downtown and industrial/residential fringe surrounding the city limits. Samples were collected during a bypass period when the interceptor line was drained for repairs. This situation afforded the sample crews the opportunity to enter the sewerage system and collect samples.

Wet Weather Sampling

Prior to initiation of the wet weather sampling, a number of locations were calibrated for flow monitoring. Because CSF either flows over the regulator or to the POTW, only two of the three flows (i.e., CSF, CSO, or flow to POTW) were monitored. The third flow was obtained by subtraction.

Several flow monitoring techniques were used during this study. Fluorescent dye tracing, electromagnetic velocity meters, current meters, and various surface velocity techniques were used in conjunction with depth measuring instruments such as bubbler tubes, ultrasonic level recorders, staff gauges, dippers, and acoustic level recorders. Velocity and depth measurements were used to develop stage versus discharge curves. These relationships greatly aided the field crews because by obtaining continuous depth measurements over the duration of the storm events, the respective CSF and CSO volumes and instantaneous flow rates could be determined using the stage versus discharge curves. These data were needed both to calculate pollutant masses and to composite samples.

Combined Sewer Flow Samples--

Flow proportioned composite samples were collected at each of the eight regulator locations prior to the wastewater being discharged to the POTW interceptor. These samples were used to characterize the CSF for a given storm event. Sample locations were situated in the immediate vicinity of the flow monitoring stations. Sample periods extended from the start of a storm event, when the flow rate began to rise as a result of runoff entering the system, until the conclusion of the storm event when the flow receded to the dry weather flow level.

Automatic samplers were programmed to draw fixed aliquot samples at predetermined flow volume intervals (flow intervals varied from storm to storm depending on the storm intensity forecast) at the Lander and Michigan locations in Seattle. Composite samples at the other six regulators were obtained by collecting manual grab samples at a fixed time interval, then compositing these grab samples into a single sample proportional to the flow rate at the time the grab aliquot was collected. Grab samples for VOC, O&G and CN were collected at constant time intervals, preserved, forwarded to the respective laboratories, composited in the laboratory proportional to the flow rate, and then analyzed.

Combined Sewer Overflow Samples--

Flow proportioned composite samples and grab samples for VOC, O&G and CN were collected similar to the CSF samples. The sample period was during the time of the overflow. Short overflow periods required that the time interval between the collection of aliquot samples be shorter. Care was taken to correlate sample collection times with overflow volumes.

For most of the sampling episodes, overflow samples were collected from the same location as the CSF samples. The characteristics of these two flows during overflow periods are generally the same, because turbulent flow conditions eliminated any stratified flow patterns. The duration of the sample collection period and the proportions in which these samples were composited distinguishes the CSO sample from the CSF sample.

First Flush Samples--

Flow proportioned composite samples and grab samples for VOC, O&G and CN were collected at the CSF sample location to document the characteristics of any observed "first flush" phenomenon.

First flush sampling during several other studies focused on collecting numerous grab samples throughout a storm event and analyzing each individual grab sample for the pollutants of concern. Due to the cost and number of samples associated with such an endeavor for priority toxic pollutant sampling, a different approach to defining the first flush period was considered. The changes in total solids (TS) concentration, total suspended solids (TSS) concentration, settleable solids (SS) concentration, temperature, and conductivity of the wastewater during wet weather periods were monitored to identify such an approach.

Use of solids analyses (TS, TSS and SS) to define the first flush period involved the collection of samples at equal time intervals, and the analysis of each sample for the various solid constituents at the conclusion of the storm event. By plotting the solids concentration with respect to time, changes in the wastewater solids composition as a result of dilution were determined. The extensive on-site analytical work and the lack of an observable drastic change in solids concentration made this approach impractical.

The lack of sensitivity of temperature (change of only 3°C to 5°C throughout a storm event) requires much discretion by the field sampling crews to explicitly identify the first flush period. Therefore, this approach to define the first flush period was not further pursued.

Conductivity is the measure of the ability of the wastewater to conduct an electrical current. This measure is proportional to the ionic concentration of the wastewater. For wastewaters with discernable amounts of free acids or alkalinity (such as those anticipated during the CSO study), the conductivity of the wastewater should approximate 30 to 50 percent of the total dissolved solids concentration of the wastewater. The advantages of using conductivity readings as a measure of the first flush period are: 1) no sampling and analysis are required; 2) continuous instantaneous readouts are possible in the field; and 3) the conductivity range is sensitive to changes in the characteristic of the wastewater. For these reasons, the change in conductivity of the wastewater was selected as the indicator to identify the first flush period.

In-situ conductivity readings were continuously recorded at the CSF sample location throughout the duration of each storm event. Conductivity readings of 300 to 2,000 micromhos per centimeter (μmhos/cm) were recorded for domestic/industrial wastewater free of wet weather influences. When a storm event began, the conductivity generally remained unchanged. However, as the storm event progressed, the wastewater became diluted and the ionic concentration of the combined sanitary/storm water runoff decreased. The conductivity normally decreased slowly at first, and then rapidly dropped to approximately 75 to 150 μmhos/cm. Throughout this study, the first flush period was defined as the duration from the beginning of a storm event to the rapid decline in the conductance of the CSF wastewater. This period, for the most part, extended 30 to 60 minutes.

Composite aliquots and grab samples for VOC and CN were collected at the CSF sample location during the first flush period. At the conclusion of the storm event, the aliquots and grab samples collected during the first flush period were composited on a flow-proportioned basis. These samples were used to characterize the combined sewer wastewater flow during the first flush period.

Runoff Samples--

Composite aliquots and grab samples for VOC, O&G and CN were collected at street level as the runoff entered the inlet structure. Samples were collected from two separate inlet locations per catchment area and later blended to form a single runoff sample per catchment. All runoff samples were collected on a constant time-constant volume basis. The inlet locations were selected to best represent the overall catchment area land use. Locations for runoff sampling were selected after observing the inlets during several storm events.

Precipitation Samples--

Rainfall samples were collected during each of the sampling episodes. One rainfall collector per catchment area was used to collect precipitation samples. If, as in most instances, samples were collected in both catchment areas in a city, the two precipitation samples were combined to form a single sample per storm event for a city. The collectors used throughout this program were constructed of stainless steel and were sized so that a three-gallon sample was obtained for a 0.25-in. storm event (16 square feet of surface area). A volume of three gallons is necessary for the complete spectrum of pollutant analysis.

Since rainfall amounts and intensities may have a major influence on the character and occurrence of combined sewer overflows, specific rainfall data for each catchment area were also collected. One recording rain gauge was situated in each catchment area and rainfall volumes and intensities were obtained at 15 minute intervals.

ANALYTICAL TECHNIQUES

Wastewater samples were analyzed for the 125 priority toxic pollutants and the selected conventional and nonconventional pollutants listed in Table 5.1. The analytical procedures for toxic organic pollutants are those described in the EPA Methods for Organic Chemical Analysis of Municipal and Industrial Wastewaters (27). The majority of the samples were analyzed by isotope dilution (EPA methods 1624 and 1625). This method entails adjusting the analytical results based on the respective samples' surrogate compounds recoveries. However, the samples from the Lander and Michigan catchment areas were analyzed using EPA methods 624 and 625. Analytical results are not adjusted for recoveries using these methods. Conventional and nonconventional analyses were performed in accordance with EPA Methods for Chemical Analysis of Water and Waste (28). Table 5.2 summarizes the analytical methods used during this study.

SYNOPSIS OF SAMPLING EVENTS

Prior to initiating sample collection activities, each of the eight catchment area sampling locations were flow calibrated by developing stage height versus discharge relationships. Upon completion of flow calibration, a

TABLE 5.2 SUMMARY OF ANALYTICAL METHODS

PARAMETER	METHOD NUMBER[1]	DESCRIPTION
Biochemical Oxygen Demand (5-day)	405.1	Five day @ 20°C
Chemical Oxygen Demand	410.4	Colorimetric-Manual
Total Organic Carbon	415.1	Combustion-Infrared
Residue		
Total Solids	160.3	Gravimetric-Dried @ 103-105°C
Total Suspended	160.2	Gravimetric-Dried @ 103-105°C
Total Volatile Suspended	160.4	Gravimetric-Dried @ 550°C
Total Dissolved	160.1	Gravimetric-Dried @ 180°C
Total Volatile Dissolved	160.1	Gravimetric-Dried @ 550°C
Total Volatile Solids	160.4	Gravimetric-Dried @ 550°C
Settleable Solids	160.5	Gravimetric
Chloride	325.3	Titrimetric-Mercuric Nitrate
Ammonia as Nitrogen	350.2	Titrimetric-Distillation Procedure
Total Phenols	420.1	Spectrophotometric, Manual (4-AAP with Distillation)
Oil and Grease	413.1	Gravimetric-Separatory Funnel Extraction
Cyanide, Total	335.2	Spectrophotometric
Metals		
A. Aluminum, Barium, Beryllium, Boron, Cadmium, Calcium, Chromium, Cobalt, Copper, Iron, Lead, Magnesium, Manganese, Molybdenum, Nickel, Sodium, Tin, Titanium, Vanadium, Yttrium, Zinc		Inductively Coupled Plasma Emission Spectrometry
B. Antimony, Arsenic, Mercury, Selenium, Silver, Thallium		Flameless Atomic Absorption Spectrometry
Organics		
A. Purgeables	1624[2] 624[3]	Gas Chromatography/Mass Spectrometry
B. Acid Extractable, Base-Neutrals and Pesticides	1625[2] 625[3]	Gas Chromatography/Mass Spectrometry

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[1] Unless otherwise specified, methods are from: Methods for Chemical Analysis of Water and Waste, U.S. EPA-600/4-79-020, 1979.

[2] Isotope Dilution Gas Chromatography-Mass Spectrometry for the Determination of Priority Pollutants in Industrial Pollutants, U.S. EPA, 1981.

[3] Methods 624 and 625 were used for samples collected at the Lander and Michigan locations only.

total of 135 wastewater and six sediment samples were collected during four dry weather sampling episodes (one per city) and 17 wet weather sampling events. Table 5.3 summarizes these events; Appendix B presents the wet weather hydrographs for these events. A brief description of the sampling episodes is presented below.

Providence, Rhode Island

May 18-19, 1982: Dry weather background samples were collected at both the Dexter @ Huntington and Ernest @ Allens regulators. An eight-day antecedent dry weather period preceded the sampling episode. The wastewater from the Ernest @ Allens location varied greatly in both color (dark green to a light red) and pH (from 10 to less than 2) throughout the sampling period. Industrial activities were minimal from 1800 hours on May 18 to 0600 hours the next morning. This point was evidenced by the dramatic decrease in flow during this period. To a lesser extent, changes in the wastewater flow, pH and color followed a similar pattern at the Dexter @ Huntington location. Solvent odors were documented at both locations, the odors being most dominant in the 1600-1800 hour time period. Sediment samples were collected from the Ernest @ Allens location. Grab samples from a number of locations were composited to form a single sediment sample. Sediment samples were not collected from the Dexter @ Huntington location due to a lack of any substantial solids accumulations in the sewers.

July 19, 1982: A six-day dry weather period preceded this storm event. Only the Ernest @ Allens location was sampled. The rainfall was gentle at the beginning of the storm event, peaking at an intensity of 1.5 inches/hour, 30 minutes after the beginning of the storm period. Solvent odors were heavy at the sample location, and multi-colored oil films were observed both in the runoff samples and at the regulator location. Clogged catchbasins within the drainage area resulted in some runoff "overflowing" to adjacent areas.

August 8, 1982: Four days of dry-hot weather preceded the storm front that deposited 0.30 inches during a 3-hour period at the Dexter @ Huntington location. The shower activities consisted of two distinct 0.15 inch rainfalls. The sampling period coincided with a state-observed holiday. For this reason, industrial activities were minimal. Solvent odors were prevalent during the sampling period, especially during the initial portion of the runoff event. Oil films were present in the majority of samples collected at the regulator location.

August 25, 1982: Both the Ernest @ Allens and Dexter @ Huntington locations were sampled during this storm event. Again, as a result of clogged catchbasins, runoff bypassed the catchbasins in the Ernest @ Allens catchment and overflowed to adjacent drainage areas. Clogged catchbasins in the Dexter @ Huntington drainage area resulted in temporary storage of storm water on the streets. Solvent odors again were prevalent.

TABLE 5.3. SUMMARY OF SAMPLING EPISODES.

EVENT CODE	LOCATION	DATE (1982)	DAY OF WEEK	TIME OF SAMPLE PERIOD	ANTECEDENT DRY WEATHER PERIOD (days)	RAINFALL ACCUMULATION (inches)	MAX. INTENSITY DURING A 15-MINUTE PERIOD (inch/hour)	AVERAGE INTENSITY (inch/hr)	VOLUME TO REGULATOR (gallons)
Dry Wea.	Dexter at Huntington	May 18, 19	Tues-Wed	0830-0830	8	--	--	--	1,200,000
Storm 1B		August 8	Sun	0540-0915	4	0.30	0.4	0.10	651,000
Storm 2		August 25	Wed	0905-1505	2	0.52	NA	0.17	1,358,000
Storm 3		September 20	Mon	1740-2035	5	0.26	0.4	0.13	580,400
Dry Wea.	Ernest at Allens	May 18, 19	Tues-Wed	0830-0830	8	--	--	--	740,000
Storm 1A		July 19	Mon	1800-2030	6	0.70	1.5	0.65	567,000
Storm 2		August 25	Wed	1010-1500	2	0.42	NA	0.14	761,000
Storm 3		September 20	Mon	1705-1955	5	0.25	0.14	0.13	323,400
Dry Wea.	Lander	March 16, 17	Tues-Wed	0930-0930	2	--	--	--	2,580,000
Storm 1		April 14	Wed	0930-1400	0.33	0.17	0.16	0.03	3,010,000
Storm 2		June 30	Wed	0830-1200	16	0.21	0.16	0.08	1,940,000
Storm 3		October 6	Wed	0600-1130	4	0.42	0.24	0.10	5,680,000
Dry Wea.	Michigan	March 16, 17	Tues-Wed	0930-0930	2	--	--	--	4,180,000
Storm 1		April 14	Wed	1000-1430	0.33	0.26	0.2	0.05	1,570,000
Storm 2		June 30	Wed	0845-1200	16	0.18	0.16	0.07	2,160,000
Storm 3		October 6	Wed	0600-1130	4	0.38	0.28	0.10	3,590,000
Dry Wea.	Branch	August 4, 5	Wed-Thurs	0730-0730	15	--	--	--	3,360,000
Storm 1		October 6	Wed	1555-1945	4	1.17	1.5	0.45	19,500,000
Storm 2		October 19	Tues	2045-2400	10	0.57	0.70	0.23	9,810,000
Storm 3		December 2	Thurs	1510-2105	3.5	0.59	0.40	0.09	22,010,000
Dry Wea.	Prairie	August 4, 5	Wed-Thurs	0730-0730	15	--	--	--	1,860,000
Storm 1		October 6	Wed	1500-1830	4	1.05	1.0	0.35	3,740,000
Storm 2		October 19	Tues	2030-2250	10	0.59	0.76	0.25	2,280,000
Storm 3		December 2	Thurs	1600-2115	3.5	0.73	1.0	0.12	6,980,000
Dry Wea.	Phalen	August 4, 5	Wed-Thurs	1130-1130	10	--	--	--	2,340,000
Storm 1B		October 19, 20	Tues-Wed	1345-0430	4	1.99	0.44	0.17	24,487,000
Storm 2B		November 9	Tues	1600-1845	0.33	0.13	0.12	0.07	2,603,000
Dry Wea.	Eustis	August 4, 5	Wed-Thurs	1130-1130	10	--	--	--	562,000
Storm 1A		October 9	Sat	1735-1915	2	0.10	0.24	0.16	98,000
Storm 2A		November 11	Thurs	1355-2155	1	0.65	0.32	0.08	922,000

September 20, 1982: An antecedent dry weather period of five days preceded the sampling effort. The storm event initially was a light drizzle, developing eventually into a shower activity with an average intensity of 0.13 inches/hour. Clogged catchbasins again produced the same results as observed during previous storm events in both drainage areas.

Seattle, Washington

March 16-17, 1982: Dry weather background samples were collected at both the Lander and Michigan regulator locations. A 48-hour dry weather period preceded the initiation of the sampling period. The wastewater from the Michigan drainage area had the smell and appearance of a dilute gray, domestic wastewater. In contrast, the wastewater originating from the Lander catchment area had a distinct solvent odor. In addition, a jet-black petroleum-based discharge was observed from 1530 to 1630 hours at the Lander location. Sediment samples were collected during the dry weather background sampling episode. However, because that sample was lost, a sediment sample was collected again on March 24, 1982 (after a 10 day antecedent dry weather period).

April 14, 1982: Only eight hours of dry weather preceded this storm event. The showers from the previous storm had resulted in overflow occurrences at both locations, and at the Lander site, overflow from the previous event was still occurring at the initiation of the sampling period. As a result, the first flush conductivity readings and settleable solid concentrations yielded no conclusive results as to the existence of a first flush period. For this reason, analytical results for this storm event characterize the second wave of rainfall activity associated with a frontal system. In particular, the first flush samples from both locations should be viewed as samples representing the initial portion of the storm event, but not necessarily a first flush period.

June 30, 1982: With the exception of a sparse shower on June 28, 1982, an antecedent dry weather period of 16 days preceded the storm event sampled at the Michigan and Lander locations. Shower activities began about 0800 hours, however, sample crews were not able to mobilize until 0830 hours. The wet weather background samples collected were not considered, therefore, to be free of urban runoff. Showers were intermittent, as reflected by the "peaks and valleys" on the storm hydrographs. The determination of a first flush period was difficult, because no definitive change in the conductivity of the wastewater at either location was observed.

October 6, 1982: Four days of antecedent dry weather conditions preceded the third and most intense rainfall event sampled at the Lander and Michigan regulators. Even with this antecedent dry weather period and the moderate intensity of the storm event (average intensity of 0.1 inch of rainfall per hour), a definitive first flush period based on conductivity readings was not obtainable at the Michigan location. Excessive oil in the wastewater may have prevented accurate conductivity readings at this location. A pronounced change in the conductivity at the Lander location was observed, however.

St. Louis, Missouri

August 4-5, 1982: Dry weather background sampling at both the Branch and Prairie locations were preceded by a 15-day antecedent dry weather period. The wastewater at the Branch gatewell displayed a strong, noxious, soapy odor at the 0730 and 0830 sample intervals on August 4. The odor gradually dissipated as the morning progressed. The same odor was again noticed in the 0530 sample on August 5, and was significantly stronger in the 0630 sample. The 1330 and 1430 samples taken at the Branch regulator contained styrofoam particles.

October 6, 1982: A brief shower occurred in the Branch catchment area prior to wet weather background sampling, though no precipitation fell at the regulator. Combined sewer flow rates were near dry weather conditions at the time the wet weather background samples were taken. Combined sewer flow samples were taken from 1557 until 1945. The first flush was not well documented at the Branch Street location due to an equipment failure. In retrospect, the first flush sample collected is not an accurate representation of the first flush period and is not included in subsequent first flush data analysis. At the Branch regulator location, styrofoam beads were again observed in abundance, as noticed during the dry weather background sampling.

At the Prairie regulator, oil and grease was visible in a number of samples taken throughout the sampling period. Strong organic solvent odors were also noted at the Prairie location.

October 19, 1982: A 10-day antecedent dry weather period preceded the second storm event sampled in St. Louis. As occurred during the first storm event, oil and grease was again visible in several samples collected at the Prairie regulator. A well-defined first flush period was observed from 2030 until 2150 hours at the Prairie location; the first flush period was not as pronounced at the Branch location. The storm event sampled was a moderate storm that resulted in a total of 0.59 inches of rain with a maximum intensity of 0.7 inches per hour. It lasted for 2.5 hours.

December 2, 1982: A thunderstorm resulted in approximately 0.73 inches of rain during a six-hour period (average intensity of 0.12 inch/hour) with 0.26 inches of the total falling during a fifteen minute period (1.04 inch/hour average intensity). A 3.5-day dry weather period preceded the initiation of wet weather sampling. A total of 3.3 inches of rain fell during the 24-hour period following the initial six hour period. However, only the initial frontal system that deposited 0.73 inches of rain was sampled. Oil and grease was visible in a number of samples collected during the sampling periods at both locations. The samples varied in color throughout the storm event, ranging from dark red to deep gray. No samples showed any distinct color dilution even though flow rates exceeded 150 mgd at both locations. The composite sample from the Branch runoff location was broken in transit; therefore, only VOC runoff sample results were available.

St. Paul, Minnesota

Due to the localized nature of the thunderstorms that occurred in the St. Paul area during the sampling phase of this study, the two catchment areas were never sampled simultaneously. When precipitation was intense in one catchment area, little, if any, rainfall was observed in the other drainage area. This presented mobilization problems for the sampling crews. Consequently, after dry weather sampling was completed, four separate storm events were sampled (two events in each catchment area).

August 4-5, 1982: Dry weather background sampling at both the Phalen and Eustis regulator locations were preceded by ten days of antecedent dry weather conditions. A strong odor of fermentation and grain was present at the Phalen Creek location throughout the day and night, and was especially strong between 0300 and 0400 hours. Steam and mist rose continuously through the sampling episode and the wastewater was a murky green/brown color. This is characteristic of the discharge from the brewery immediately upstream of the sample location.

October 9, 1982: The first storm event sampled in St. Paul occurred between 1740 hours and 1910 hours and was preceded by a two day antecedent dry weather period. Sampling was conducted at the Eustis Street location. A total of 0.1 inches of precipitation fell during the storm resulting in overflow of 39,600 gallons during a 15-minute period.

October 19, 1982: Storm event two occurred from 1540 hours on October 19, 1982 until 0300 hours on October 20, 1982, and was preceded by a four day antecedent dry weather period. A total of 1.99 inches of rain fell during this sampling episode, which took place in the Phalen Street catchment area. The velocity of flow was so great in the combined sewer that the sampling pole used to hold oil and grease sample bottles was sheared during the sampling episode. Therefore, no oil and grease samples were taken at the Phalen storm location. There was a brief respite from rainfall activity around 1815 hours, and flow in the storm sewer returned to the normal dry weather depth of approximately six inches. The storm sewer sampling activities were terminated at this time. Runoff also ceased after the initial period of precipitation and crew members stopped collecting runoff samples. CSO and CSF sampling extended the full duration of the storm period.

November 9, 1982: The third sampling episode took place at the Phalen catchment area on November 9, 1982. A total of 0.13 inches of rain fell between the hours of 1550 and 1840. Earlier in the day, between 0630 and 0830 hours, there was a storm event in the catchment area that resulted in 0.11 inches of rainfall. However, this 0.11-inch storm event did not result in a significant increase in flow in the combined sewer system. During the sampling period, combined sewer flows were elevated. Conductivity readings were not taken for the first 35 minutes of sampling due to an oversight by the field crew. For this reason it is felt the first flush period was not documented for this sampling episode and these data are not included in subsequent first flush data analyes. No precipitation samples were collected for this storm event.

November 11, 1982: The final storm event that was sampled occured on November 11, 1982. Sampling was conducted in the Eustis Street catchment area from 1355 until 2150 hours. During this period, a total of 0.65 inches of rain fell. No major field sampling problems were encountered.

SECTION 6

DATA EVALUATION

Flow hydrographs for each sampling episode are presented in Appendix B. Analytical results for dry and wet weather sampling episodes are presented in Appendix C. Percent occurrences, mass calculations, and summary analyses presented in this section are based on these data. One hundred and thirty-five samples were analyzed for selected conventional and nonconventional pollutants as well as for 125 priority toxic pollutants. Several blank samples (23), duplicate samples (21), and spiked samples (107) were also analyzed as part of a quality assurance/quality control program (QA/QC). The QA/QC results are summarized in this section.

FACTORS THAT AFFECT POLLUTANTS IN CSFs AND CSOs

Factors that affect the concentration of pollutants in CSFs and CSOs may be divided into two categories: 1) those that affect the quality of the CSF and CSO, and 2) those that affect the quantity of CSF and CSO.

The first quality related factor is the characteristic of the background wastewater. The background pollutant characteristics are dependent on the industries that discharge to the collection system and the residential and commercial wastewater contributions. The day of the week and time of day may impact the discharge of industrial wastewaters and, therefore, may impact the quality of the CSFs and CSOs.

The quality of the runoff from a drainage area is another factor that affects the quality of CSFs and CSOs. As discussed later, the quality of the runoff particularly impacts the lead, zinc, bis(2-ethylhexyl)phthalate, di-n-butyl phthalate, fluoranthene, TSS, and to a lesser extent COD concentrations in CSOs.

Resuspension of settled material in the combined sewer system also affects the quality of CSF. The characteristics of resuspended material is dependent on the composition of the wastewaters discharged during dry weather conditions.

Land use also may impact the quality of CSF and CSOs. For example, well vegetated surfaces should show a low mobility of the metals deposited on those surfaces from the runoff (grass and other vegetation effectively capture and retain the metals). In contrast, bituminous pavements and other impervious areas demonstrate little or no ability to remove metals from runoff. The pH of the precipitation may further complicate the metals transport mechanisms. Acid precipitation, for instance, could release metals bound in soils, especially soils with low buffering capacities. Particulate matter discharged from industrial smoke stacks and scrubbed from the atmosphere by rain droplets, although not observed in appreciable concentration during this study, is a potential land use quality factor. Storage of material in the drainage areas that may be scoured by rainfall or runoff is another potential quality determinant.

Traffic volume appears to be a critical factor in affecting the quality of runoff and, therefore, the quality of CSFs and CSOs. Not only are lead, zinc and most PAHs by-products of automobile use, but "large traffic volumes and relatively high speeds provide the energy needed at the street surface to loosen particulates" (29).

The quantity of wastewater discharged as CSF and CSO is affected by a number of variables. First, the volume of precipitation limits the quantity of water discharged to the sewerage system as runoff. Factors such as rainfall intensity, percent of land area that is pervious or impervious, slope of the drainage area, length of the antecedent dry weather conditions, and size of the drainage area all affect the percentage of precipitation that eventually becomes runoff.

Perhaps the most critical factor affecting the volume of CSO is the regulator arrangement. During this study the capacity of the spur lines that connect the regulator chambers to the interceptors and the interceptors that carry wastewaters to the POTWs varied. The Ernest @ Allens and Eustis regulators, which serviced the two smallest drainage areas, had the capacity to capture the entire combined sewer flow during certain low volume, light intensity storm events. In contrast, the Phalen and Branch regulators had very little excess capacity. Therefore, during a given storm event the majority of the combined sewer flow was discharged as CSO at the Phalen and Branch regulators.

OCCURRENCE OF PRIORITY TOXIC POLLUTANTS

For each of the 125 priority toxic pollutants listed in Table 5.1, percent occurrence in the combined sewer overflow, combined sewer flow, runoff, first flush, wet weather background, precipitation, dry weather background, and tap water samples was determined. Table 6.1 summarizes the priority toxic pollutant percent occurrences by type of sample. For this evaluation, if pollutant concentrations were below the pollutant analytical detection limit, the pollutant was assumed not to be present. For example, the analytical detection limit for arsenic is 3 ug/l. Therefore, if arsenic was not present at 3 ug/l or greater, it was assumed not to be present. Priority pollutants not detected during any of the eight sampling episodes are not listed. The percent occurrence is the number of samples in which a pollutant was detected (regardless of concentration) divided by the number of samples analyzed for that pollutant, multiplied by 100. The number in parenthesis in Table 6.1 is the number of samples analyzed.

Sixty-nine of the 125 priority pollutants were detected in at least one of the 135 samples collected during this study. Metals (all 13 elements were detected), volatile organic compounds (22 of 30 pollutants were detected), and cyanide were the most frequently detected pollutants. Eleven of the 16 polynuclear aromatic hydrocarbons (PAHs) and 10 of the 11 acid extractable compounds were detected; however, occurrences for the PAHs were more sporadic and their concentrations were generally close to the analytical detection limits. All six priority pollutant phthalate compounds were detected at least once. However, with the exception of bis(2-ethylhexyl)phthalate and di-n-butyl

TABLE 6.1
PERCENT OCCURRENCE OF PRIORITY POLLUTANTS

POLLUTANT	CSO		CSF		RUNOFF		FIRST FL		WW BKGD		PRECIPIT		DW BKGD		TAPWATER	
ZINC	100	(22)	100	(22)	100	(21)	100	(22)	100	(22)	76	(13)	100	(8)	50	(4)
COPPER	90	(22)	86	(22)	85	(21)	90	(22)	95	(22)	23	(13)	75	(8)	75	(4)
METHYLENE CHLORIDE	90	(22)	86	(22)	77	(22)	86	(22)	77	(22)	72	(11)	100	(8)	75	(4)
CHROMIUM	86	(22)	81	(22)	61	(21)	85	(22)	90	(22)	15	(13)	100	(8)	25	(4)
LEAD	86	(22)	90	(22)	76	(21)	86	(22)	54	(22)	15	(13)	37	(8)	25	(4)
BIS(2-ETHYLHEXYL)PHTHALATE	81	(22)	77	(22)	61	(21)	77	(22)	77	(22)	45	(11)	25	(8)	25	(4)
TOLUENE	77	(22)	81	(22)	31	(22)	77	(22)	68	(22)	36	(11)	87	(8)	0	(4)
1,1,1-TRICHLOROETHANE	63	(22)	54	(22)	0	(22)	68	(22)	40	(22)	0	(11)	37	(8)	0	(4)
NICKEL	59	(22)	45	(22)	23	(21)	59	(22)	59	(22)	0	(13)	50	(8)	0	(4)
TETRACHLUROETHENE	59	(22)	63	(22)	4	(22)	72	(22)	54	(22)	27	(11)	37	(8)	0	(4)
TRICHLOROETHENE	54	(22)	54	(22)	9	(22)	50	(22)	59	(22)	9	(11)	75	(8)	0	(4)
SILVER	45	(22)	36	(22)	9	(21)	36	(22)	54	(22)	15	(13)	62	(8)	25	(4)
CADMIUM	36	(22)	36	(22)	19	(21)	31	(22)	50	(22)	23	(13)	50	(8)	0	(4)
CHLOROFORM	36	(22)	36	(22)	22	(22)	45	(22)	54	(22)	18	(11)	62	(8)	75	(4)
MERCURY	31	(22)	27	(22)	14	(21)	27	(22)	31	(22)	0	(13)	12	(8)	0	(4)
CYANIDE	31	(22)	40	(22)	9	(22)	45	(22)	63	(22)	0	(11)	62	(8)	0	(4)
PHENOL	31	(22)	13	(22)	14	(21)	31	(22)	36	(22)	18	(11)	37	(8)	0	(4)
ETHYLBENZENE	27	(22)	18	(22)	9	(22)	31	(22)	54	(22)	9	(11)	37	(8)	0	(4)
NAPHTHALENE	22	(22)	22	(22)	0	(21)	36	(22)	27	(22)	0	(11)	12	(8)	0	(4)
DI-N-BUTYL PHTHALATE	22	(22)	36	(22)	19	(21)	40	(22)	40	(22)	0	(11)	12	(8)	0	(4)
ARSENIC	18	(22)	22	(22)	23	(21)	13	(22)	13	(22)	7	(13)	0	(8)	0	(4)
1,1,2-TRICHLOROETHANE	18	(22)	18	(22)	13	(22)	13	(22)	13	(22)	0	(11)	25	(8)	0	(4)
TRANS-1,2-DICHLOROETHENE	18	(22)	18	(22)	0	(22)	36	(22)	45	(22)	0	(11)	25	(8)	0	(4)
FLUORANTHENE	18	(22)	4	(22)	9	(21)	22	(22)	0	(22)	0	(11)	0	(8)	0	(4)
2,4-DIMETHYLPHENOL	18	(22)	27	(22)	14	(21)	31	(22)	27	(22)	9	(11)	12	(8)	0	(4)
ANTIMONY	9	(22)	9	(22)	19	(21)	9	(22)	9	(22)	0	(13)	0	(8)	0	(4)
BERYLLIUM	9	(22)	9	(22)	19	(21)	9	(22)	9	(22)	23	(13)	25	(8)	25	(4)
BENZENE	9	(22)	0	(22)	0	(22)	4	(22)	13	(22)	0	(11)	12	(8)	0	(4)
VINYL CHLORIDE	9	(22)	4	(22)	0	(22)	9	(22)	9	(22)	0	(11)	12	(8)	0	(4)
BENZO(K)FLUORANTHENE	9	(22)	4	(22)	4	(21)	4	(22)	0	(22)	0	(11)	0	(8)	0	(4)
PHENANTHRENE	9	(22)	13	(22)	0	(21)	13	(22)	9	(22)	0	(11)	0	(8)	0	(4)
PYRENE	9	(22)	9	(22)	0	(21)	18	(22)	0	(22)	0	(11)	0	(8)	0	(4)
BENZO(A)ANTHRACENE	9	(22)	0	(22)	4	(21)	13	(22)	0	(22)	0	(11)	0	(8)	0	(4)
4-CHLORO-3-METHYLPHENOL	9	(22)	9	(22)	4	(21)	13	(22)	13	(22)	9	(11)	12	(8)	0	(4)
THALLIUM	4	(22)	0	(22)	0	(21)	4	(22)	4	(22)	0	(13)	0	(8)	0	(4)
CHLOROBENZENE	4	(22)	4	(22)	4	(22)	0	(22)	4	(22)	0	(11)	0	(8)	0	(4)
1,1-DICHLOROETHANE	4	(22)	9	(22)	4	(22)	4	(22)	9	(22)	9	(11)	25	(8)	0	(4)
1,2-DICHLOROETHANE	4	(22)	4	(22)	0	(22)	0	(22)	0	(22)	0	(11)	0	(8)	0	(4)
1,2-DICHLOROPROPANE	4	(22)	13	(22)	0	(22)	4	(22)	4	(22)	0	(11)	0	(8)	0	(4)
BENZO(B)FLUORANTHENE	4	(22)	9	(22)	4	(21)	4	(22)	0	(22)	0	(11)	0	(8)	0	(4)
BENZO(A)PYRENE	4	(22)	4	(22)	0	(21)	9	(22)	0	(22)	0	(11)	0	(8)	0	(4)
1,4-DICHLOROBENZENE	4	(22)	4	(22)	0	(21)	4	(22)	13	(22)	0	(11)	0	(8)	0	(4)
DI-N-OCTYL PHTHALATE	4	(22)	0	(22)	4	(21)	0	(22)	9	(22)	0	(11)	0	(8)	0	(4)
2,4-DICHLOROPHENOL	4	(22)	4	(22)	0	(21)	0	(22)	4	(22)	0	(11)	0	(8)	0	(4)
PENTACHLOROPHENOL	4	(22)	4	(22)	4	(21)	4	(22)	4	(22)	0	(11)	0	(8)	0	(4)
PCB-1016	4	(22)	4	(22)	0	(21)	0	(22)	4	(22)	0	(11)	0	(8)	0	(4)
SELENIUM	0	(22)	0	(22)	0	(21)	0	(22)	0	(22)	0	(13)	25	(8)	25	(4)

POLLUTANTS NOT LISTED WERE NEVER DETECTED
NUMBERS IN PARENTHESES ARE THE TOTAL NUMBER OF SAMPLES ANALYZED

TABLE 6.1
PERCENT OCCURRENCE OF PRIORITY POLLUTANTS

POLLUTANT	CSO	CSF	RUNOFF	FIRST FL	WW BKGD	PRECIPIT	DW BKGD	TAPWATER
CARBON TETRACHLORIDE	0 (22)	4 (22)	0 (22)	0 (22)	0 (22)	0 (11)	0 (8)	25 (4)
BROMOFORM	0 (22)	4 (22)	0 (22)	0 (22)	0 (22)	0 (11)	12 (8)	0 (4)
ACRYLONITRILE	0 (22)	4 (22)	0 (22)	0 (22)	4 (22)	0 (11)	0 (8)	0 (4)
BROMOMETHANE	0 (22)	0 (22)	0 (22)	0 (22)	9 (22)	0 (11)	0 (8)	0 (4)
CHLOROMETHANE	0 (22)	0 (22)	0 (22)	0 (22)	4 (22)	0 (11)	0 (8)	0 (4)
1,1-DICHLOROETHENE	0 (22)	9 (22)	0 (22)	0 (22)	9 (22)	0 (11)	25 (8)	0 (4)
1,1,2,2-TETRACHLOROETHANE	0 (22)	0 (22)	0 (22)	4 (22)	0 (22)	0 (11)	12 (8)	0 (4)
ACENAPHTHENE	0 (22)	0 (22)	0 (21)	0 (22)	4 (22)	0 (11)	0 (8)	0 (4)
ANTHRACENE	0 (22)	0 (22)	4 (21)	4 (22)	0 (22)	0 (11)	0 (8)	0 (4)
BIS(2-CHLOROISOPROPYL)ETHER	0 (22)	0 (22)	0 (21)	4 (22)	0 (22)	0 (11)	0 (8)	0 (4)
BUTYL BENZYL PHTHALATE	0 (22)	0 (22)	4 (21)	4 (22)	0 (22)	0 (11)	0 (8)	0 (4)
CHRYSENE	0 (22)	0 (22)	4 (21)	0 (22)	0 (22)	0 (11)	0 (8)	0 (4)
DIETHYLPHTHALATE	0 (22)	0 (22)	0 (21)	0 (22)	9 (22)	0 (11)	37 (8)	0 (4)
DIMETHYLPHTHALATE	0 (22)	4 (22)	0 (21)	0 (22)	13 (22)	0 (11)	0 (8)	0 (4)
HEXACHLOROETHANE	0 (22)	0 (22)	4 (21)	0 (22)	0 (22)	0 (11)	0 (8)	0 (4)
N-NITROSODIPHENYLAMINE	0 (22)	0 (22)	0 (21)	0 (22)	4 (22)	0 (11)	0 (8)	0 (4)
1,2-DICHLOROBENZENE	0 (22)	0 (22)	0 (21)	4 (22)	4 (22)	0 (11)	0 (8)	0 (4)
2-CHLOROPHENOL	0 (22)	4 (22)	0 (21)	0 (22)	0 (22)	0 (11)	0 (8)	0 (4)
2-NITROPHENOL	0 (22)	4 (22)	0 (21)	0 (22)	0 (22)	0 (11)	0 (8)	0 (4)
2,4-DINITROPHENOL	0 (22)	4 (22)	0 (21)	0 (22)	0 (22)	0 (11)	0 (8)	0 (4)
2,4,6-TRICHLOROPHENOL	0 (22)	4 (22)	0 (21)	0 (22)	0 (22)	0 (11)	0 (8)	0 (4)
2-METHYL-4,6-DINITROPHENOL	0 (22)	4 (22)	0 (21)	0 (22)	0 (22)	0 (11)	0 (8)	0 (4)

POLLUTANTS NOT LISTED WERE NEVER DETECTED
NUMBERS IN PARENTHESES ARE THE TOTAL NUMBER OF SAMPLES ANALYZED

phthalate, phthalates were observed less than five percent of the time. PCB-1016 was the only polychlorinated biphenol detected during this study. It was only detected, however, during one storm event at the Lander drainage area in Seattle.

Analytical results for the CSO samples indicate that during the 22 storm events sampled, 46 priority toxic pollutants were detected at least once in the CSO. The 46 pollutants detected include 12 of the 13 toxic metals (selenium was not detected), 15 of the 30 volatile organic compounds, eight PAHs, five acid extractable compounds, three phthalate compounds, cyanide, 1,4-dichlorobenzene, and PCB-1016. Eleven of these compounds (zinc, copper, chromium, lead, methylene chloride, toluene, 1,1,1-trichloroethane, nickel, bis(2-ethylhexyl)phthalate, trichloroethene, and tetrachloroethene) were detected 50 percent of the time or greater. Twenty-one of the 46 compounds detected were present less than 10 percent of the time. Further evaluation of the pollutants detected by drainage area revealed that the presence of toxic pollutants in CSOs is very site specific. Nickel, for instance, was never detected in the CSO samples from the Eustis or Michigan drainage areas; occurrences of nickel in samples from the Phalen, Prairie, and Branch drainage areas were sporadic and concentrations were low when nickel was detected; and nickel was detected 100 percent of the time at the Dexter @ Huntington, Ernest @ Allen, and Lander drainage areas at average concentrations of 416 µg/ℓ, 3,110 µg/ℓ and 246 µg/ℓ, respectively. The dominant industry in all three of these drainage areas is the electroplating industry.

Toxic pollutant occurrences for the wet weather background, combined sewer flow, and first flush samples generally paralleled the occurrences of toxic pollutants in CSO samples. Zinc, copper, chromium, lead, methylene chloride, toluene, and bis(2-ethylhexyl)phthalate were the toxic pollutants detected most frequently at each location. Fifty-two toxic pollutants were detected above the analytical detection limit in the combined sewer flow, in comparison to 48 and 46 pollutants in the wet weather background and first flush samples, respectively.

A comparison of percent occurrences in the wet weather background samples to those in the combined sewer flow showed a slight decrease in percent occurrences in the combined sewer flow. Cyanide, ethylbenzene, and trans-1,2-dicloroethene demonstrated the most distinct dilution patterns, decreasing from 63, 54, and 45 percent occurrences in the wet weather background samples to 40, 18, and 18 percent, respectively, in the CSF samples. A more detailed evaluation of this phenomenon is presented in the discussion of the first flush analysis.

Twenty-two runoff samples were analyzed for cyanide and VOCs; and 21 runoff samples were analyzed for acid extractable, base-neutral extractable, pesticide, and metal toxic pollutants. Zinc, copper, lead, and methylene chloride were the pollutants most often detected. Methylene chloride percent occurrences are suspected to be erroneously elevated due to laboratory contamination. The metals chromium, nickel, silver, cadmium, and mercury were all detected in a portion of the runoff samples, but not as often as they were detected in the CSO and CSF. Nine VOCs were detected in the 22 runoff samples; they were detected, however, less frequently in the runoff than in either the

CSO or CSF. Six PAHs were detected in the runoff. However, the PAHs were detected in concentrations close to the analytical detection limit.

Thirteen precipitation samples were collected during the sampling episodes. Each of the 13 samples was analyzed for toxic metals, and 11 samples were analyzed for toxic organic pollutants and cyanide. Eight of the 13 toxic metals were detected at levels above the pollutant analytical detection limit at least once in the 13 samples; seven VOC and three acid extractable pollutants were detected at least once; and bis(2-ethylhexyl)phthalate was detected five times. Only zinc (10 occurrences) and methylene chloride (8 occurrences) were detected greater than 50 percent of the time. Again, methylene chloride occurrences are suspected to be the result of laboratory contamination. No PAH compounds were detected in the precipitation samples.

One tap water sample was collected and analyzed in each of the four cities. The most frequently detected priority pollutants were copper, chloroform, and methylene chloride which were each present in three of the four samples. The methylene chloride trace concentrations are suspected to be false-positive occurrences because of laboratory contamination. Chloroform, a trihalomethane associated with chlorination of waters, was the organic toxic pollutant present at the highest average concentration (15 μg/ℓ) in tap water. Zinc was present in two of the four samples (at 110 μg/ℓ) while lead, chromium, silver, beryllium, selenium, bis(2-ethylhexyl)phthalate, and carbon tetrachloride were each detected once above their respective analytical detection limit.

COMBINED SEWER OVERFLOW (CSO) POLLUTANT EVALUATION

Twenty-two composite CSO samples were collected from the different drainage areas during this study. Each sample was a flow-proportioned representation of an overflow event. Samples were collected during high and low intensity storm events, from various land use areas, at several different types of regulator chambers, on different days of the week, at varying times of day, and from sites with unique combinations of industrial flows.

As previously mentioned, 46 priority toxic pollutants were detected at least once in the CSO samples. Table 6.2 presents a summary of the percent occurrence and mean concentration of these 46 pollutants and the percent occurrence and mean concentration values for selected conventional/nonconventional pollutants by drainage area. In addition, overall average CSO pollutant concentrations and median concentrations are presented. The median is presented to indicate the central tendency of these highly scattered data. To calculate the average and median values, organic priority pollutants were assumed to have zero concentration if the respective pollutants were reported as not detected. For the 13 toxic metals and cyanide, analytical results were reported either as a value or as less than an analytical detection limit. When a pollutant result was reported as less than the analytical detection limit, the detection limit was used to calculate the average concentration value. The true average concentration value lies somewhere between zero and the detection limit in these cases. If zero was assigned as the concentration instead of the detection limit value, the average concentrations for several pollutants would decrease slightly. Nickel and cadmium average concentrations would decrease

TABLE 6.2. COMBINED SEWER OVERFLOW POLLUTANT PERCENT OCCURRENCE AND CONCENTRATION SUMMARY BY DRAINAGE AREA

Pollutant*	Dexter @ Huntington		Ernest @ Allens		Lander		Michigan		Branch		Prairie		Phalen		Eustis		CSO Average**		CSO Median**
Priority Pollutants																			
Metals:																			
Zinc	100	(614)	100	(1,411)	100	(773)	100	(203)	100	(407)	100	(453)	100	(190)	100	(224)	100	(569)	(430)
Copper	100	(479)	100	(652)	100	(467)	100	(55)	100	(96)	100	(125)	50	(66)	50	(36)	90	(263)	(111)
Chromium	100	(72)	100	(350)	100	(197)	100	(110)	100	(37)	100	(56)	ND		50	(29)	86	(117)	(64)
Lead	100	(353)	33	(290)	100	(250)	100	(180)	100	(458)	100	(500)	50	(175)	100	(403)	86	(329)	(322)
Nickel	100	(416)	100	(3,110)	100	(246)	ND		33	(61)	67	(86)	50	(75)	ND		59	(553)	(81)
Silver	66	(13)	66	(20)	66	(1)	100	(3)	33	(4)	ND		ND		ND		45	(6)	(2)
Cadmium	33	(12)	33	(10)	66	(28)	33	(6)	33	(13)	33	(200)	50	(13)	ND		36	(38)	(13)
Mercury	ND		ND		33	(<1)	66	(1)	66	(<1)	66	(<1)	ND		ND		31	(1)	(<1)
Arsenic	ND		ND		33	(18)	66	(18)	33	(10)	ND		ND		ND		18	(13)	(<DL)
Antimony	ND		ND		66	(3)	ND		ND		ND		ND		ND		9	(<1)	(<DL)
Beryllium	33	(4)	33	(7)	ND		ND		ND		ND		ND		ND		9	(<1)	(<DL)
Thallium	ND		33	(36)	ND		ND		ND		ND		ND		ND		9	(5)	(<DL)
Total Toxic Metals		(1,960)		(5,900)		(1,980)		(580)		(1,090)		(1,420)		(520)		(690)		(1,890)	(1,255)
Others:																			
Cyanide	67	(291)	67	(5,640)	67	(788)	ND		ND		33	(380)	ND		ND		31	(977)	(146)
Volatiles:																			
Methylene Chloride	100	(22)	100	(124)	66	(51)	66	(127)	100	(21)	100	(335)	100	(17)	100	(8)	90	(96)	(37)
Toluene	100	(11)	100	(6.5)	33	(42)	66	(8)	66	(5)	100	(187)	100	(3)	50	(1)	77	(36)	(7)
1,1,1-Trichloroethane	100	(134)	100	(187)	33	(3)	66	(20)	100	(33)	66	(2)	ND		ND		63	(52)	(11)
Trichloroethene	100	(945)	100	(92)	33	(203)	66	(54)	66	(2)	66	(10)	ND		ND		54	(178)	(32)
Tetrachloroethene	100	(491)	100	(77)	33	(3)	66	(19)	66	(2)	33	(56)	ND		ND		59	(88)	(11)
Chloroform	ND		33	(1)	ND		ND		66	(3)	66	(40)	100	(6)	50	(2)	36	(7)	(1)
Ethylbenzene	33	(3)	ND		ND		ND		66	(2)	100	(37)	ND		ND		27	(6)	(<DL)
1,1,2-Trichloroethane	100	(10)	33	(1)	ND		ND		ND		ND		ND		ND		18	(2)	(<DL)
Trans-1,2-Dichloroethane	100	(108)	ND		ND		ND		ND		33	(1)	ND		ND		18	(15)	(<DL)
Benzene	ND		ND		ND		ND		33	(1)	33	<1	ND		ND		9	(<1)	(<DL)
Vinyl Chloride	66	(1)	ND		ND		ND		ND		ND		ND		ND		9	(<1)	(<DL)
Chlorobenzene	ND		ND		ND		ND		33	(1)	ND		ND		ND		4	(<1)	(<DL)
1,1-Dichloroethane	ND		33	(1)	ND		ND		ND		ND		ND		ND		4	(<1)	(<DL)
1,2-Dichlorethane	ND		ND		ND		ND		ND		33	(1)	ND		ND		4	(<1)	(<DL)
1,2-Dichloropropane	ND		ND		ND		ND		ND		ND		50	(2)	ND		4	(<1)	(<DL)
Total Toxic Volatile Organics		(1,730)		(490)		(300)		(230)		(70)		(670)		(30)		(10)		(480)	(390)

<DL - Less than Detection Limit.
ND - Not Detected.
Number in parenthesis is the average or median concentration.
Priority pollutants not listed were never detected in CSOs.
* All units in μg/l unless otherwise noted.
** Values are for the eight average drainage area concentrations.

TABLE 6.2. COMBINED SEWER OVERFLOW PERCENT OCCURRENCE AND CONCENTRATION SUMMARY BY DRAINAGE AREA (continued)

Pollutant*	Dexter @ Huntington	Ernest @ Allens	Lander	Michigan	Branch	Prairie	Phalen	Eustis	CSO Average**	CSO Median**
Priority Pollutants										
Acid Extractable:										
Phenol	ND	ND	66 (7)	33 (1)	ND	100 (165)	50 (5)	ND	31 (24)	(1)
2,4-Dimethylphenol	ND	ND	ND	33 (2)	ND	100 (111)	ND	ND	18 (15)	(<DL)
4-Chloro-3-Methylphenol	ND	ND	33 (12)	33 (3)	ND	ND	ND	ND	9 (<2)	(<DL)
2,4-Dichlorophenol	ND	ND	ND	ND	ND	ND	50 (5)	ND	4 (<1)	(<DL)
Pentachlorophenol	ND	ND	ND	ND	ND	ND	50 (6)	ND	4 (<1)	(<DL)
Total Acids	—	—	(20)	(6)	—	(280)	(15)	—	(42)	(3)
Base-Neutral Extractable:										
Bis(2-Ethylhexyl)phthalate	100 (30)	66 (5)	66 (12)	33 (4)	100 (12)	100 (25)	100 (18)	100 (21)	81 (16)	(19)
Naphthalene	33 (4)	ND	33 (<1)	ND	ND	100 (6)	ND	ND	22 (2)	(<DL)
Di-n-butyl phthalate	66 (6)	ND	ND	33 (<1)	33 (1)	ND	ND	50 (5)	22 (2)	(<DL)
Fluoranthene	ND	ND	ND	ND	66 (3)	ND	50 (7)	50 (4)	18 (1)	(<DL)
Benzo(k)fluoranthene	ND	ND	ND	ND	33 (1)	ND	ND	50 (3)	9 (<1)	(<DL)
Phenanthrene	33 (2)	ND	ND	ND	ND	ND	ND	50 (2)	9 (<1)	(<DL)
Pyrene	ND	ND	ND	ND	33 (1)	ND	ND	50 (3)	9 (<1)	(<DL)
Benzo(a)anthracene	ND	ND	ND	ND	ND	ND	50 (3)	50 (2)	9 (<1)	(<DL)
Benzo(b)fluoranthene	ND	ND	ND	ND	ND	ND	ND	50 (1)	4 (<1)	(<DL)
Benzo(a)pyrene	ND	ND	ND	ND	ND	ND	ND	50 (2)	4 (<1)	(<DL)
1,4-Dichlorobenzene	ND	ND	33 (<1)	ND	ND	ND	ND	ND	4 (<1)	(<DL)
Di-n-octyl phthalate	ND	ND	33 (3)	ND	ND	ND	ND	ND	4 (<1)	(<DL)
Total Base-Neutrals	(41)	(5)	(15)	(4)	(18)	(32)	(28)	(43)	(21)	(23)
Pesticides:										
PCB-1016	ND	ND	33 (1)	ND	ND	ND	ND	ND	4 (<1)	(<DL)
Conventional/Nonconventional Pollutants										
BOD5 mg/ℓ	(143)	(15)	(83)	(48)	(37)	(59)	(180)	(15)	(65)	(54)
COD mg/ℓ	(410)	(52)	(219)	(109)	(283)	(250)	(305)	(104)	(218)	(235)
TOC mg/ℓ	(51)	(38)	(80)	(45)	(21)	(31)	(112)	(18)	(48)	(42)
TS mg/ℓ	(431)	(141)	(403)	(164)	(864)	(658)	(380)	(207)	(376)	(392)
TVS mg/ℓ	(298)	(57)	(149)	(77)	(179)	(236)	(191)	(98)	(162)	(164)
TSS mg/ℓ	(325)	(32)	(117)	(83)	(657)	(543)	(233)	(141)	(273)	(187)

<DL - Less than Detection Limit.
ND - Not Detected.
Number in parenthesis is the average or median concentration.
Priority pollutants not listed were never detected in CSOs.
* All units in μg/l unless otherwise noted.
** Values are for the eight average drainage area concentrations.

the most using this editing rule, dropping from 553 µg/l and 38 µg/l (if the detection limit value is assigned) to 532 µg/l and 34 µg/l (if zero is assumed), respectively. The use of detection limits in this analysis represents, therefore, a more conservative analytical approach.

Zinc was the only priority pollutant detected 100 percent of the time in the CSO samples. The average and median zinc concentrations of 569 µg/l and 430 µg/l, respectively, are the highest average and median concentrations of any priority pollutant found in the CSO. Average zinc concentrations for the eight drainage areas varied significantly, ranging from 1,411 µg/l at the Ernest @ Allens regulator to 190 µg/l at the Phalen regulator. With the exception of the lead concentrations, which were more consistent among the drainage areas, the average concentration of the other toxic metals varied significantly among the drainage areas. Toxic metal concentrations in general were higher at the Ernest @ Allens, Lander, and Dexter @ Huntington drainage areas (each drainage area has a number of electroplating industries) than the remaining five drainage areas. For example, the average concentrations of copper for the Ernest @ Allens, Lander, and Dexter @ Huntington regulator were 652 µg/l, 467 µg/l, and 479 µg/l, respectively. The average copper concentration for the remaining five drainage areas was 79 µg/l. The average and median copper concentrations for the combined eight drainage areas were 263 µg/l and 111 µg/l, respectively. The fact that the average is higher than the median indicates that, in general, the database is skewed upward by a few high concentrations.

Concentrations for lead demonstrated the least disparity between drainage areas. The overall average concentration of 329 µg/l is very close to the median lead concentration of 322 µg/l. The clustering or lack of substantial scattering of lead concentrations suggests that the primary source of lead (likely vehicular traffic) is the same in each drainage area. In contrast, the average nickel concentration of 553 µg/l is not similar to the median nickel concentration of 59 µg/l. Therefore, the source of nickel is most likely different in the various drainage areas.

A comparison of 24-hour composite dry weather wastewater toxic metal concentrations and CSO toxic metal concentrations shows that dry weather background concentrations in general are greater than CSO concentrations. The total toxic metal average and median concentrations for the dry weather background samples were 4,596 µg/l and 1,724 µg/l, respectively; the CSO total toxic metal average and median concentrations were 1,890 µg/l and 1,255 µg/l, respectively. CSO median concentrations for lead, zinc and cadmium exceeded the median concentration for those pollutants in the background samples. Table 6.3 presents a comparison of dry weather background pollutant concentrations to CSO concentrations observed during this study.

Organic priority pollutant occurrences were less in the CSO samples than occurrences of the toxic metals and, when detected, organic pollutants were generally present at lower concentrations. Total toxic volatile organic (TTVO) pollutant concentrations ranged from 1,730 µg/l at the Dexter @ Huntington location to 10 µg/l at the Eustis location. The average CSO TTVO concentration was 480 µg/l.

TABLE 6.3 COMPARISON OF SELECTED PRIORITY TOXIC POLLUTANT CONCENTRATIONS IN DRY WEATHER BACKGROUND SAMPLES AND IN COMBINED SEWER OVERFLOW SAMPLES

Pollutant[1]	Average Dry Weather Background Concentration[2]	Median Dry Weather Background Concentration[2]	Average CSO Concentration	Median CSO Concentration[3]
BOD5 (mg/l)	205	111	65	54
TSS (mg/l)	113	94	273	187
Cadmium	53	4	38	13
Chromium	1,528	393	117	64
Copper	735	204	263	111
Lead	138	53	329	322
Mercury (ng/l)	687	<300	<1,000	<100
Nickel	1,398	85	553	81
Silver	17	3	6	2
Zinc	658	225	569	430
Benzene	2	<DL	<1	<DL
1,1,1-Trichloroethane	118	<DL	52	11
Chloroform	9	5	7	1
1,2-trans-dichloroethylene	26	<DL	15	<DL
Ethylbenzene	40	<DL	6	<DL
Methylene Chloride	90	77	96	37
Tetrachloroethylene	11	<DL	88	11
Toluene	73	22	36	7
Trichloroethylene	48	19	178	32
Phenol	157	<DL	24	1
Naphthalene	17	<DL	2	<DL
Bis (2-ethylhexyl) Phthalate	9	<DL	16	19
Di-N-Butyl Phthlate	3	<DL	2	<DL
Total Toxic Metals	4,596	1,724	1,890	1,255
Total Toxic Volatiles	431	93	480	390
Total Toxic Acids	332	4	42	3
Total Toxic Base Neutrals	31	<DL	21	23
Total Toxic Organics	794	304	543	416

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[1] All units in ug/l unless otherwise noted.

[2] Dry weather background concentrations are the average of 24-hour composite samples collected at each regulator.

[3] Median values are for the eight drainage area average concentrations.

<DL - Less than detection limit.

Methylene chloride, which was detected in 20 of the 22 CSO samples, was present at an average concentration of 96 µg/l. However, methylene chloride was also detected in 14 out of 18 blank samples at an average concentration of 16 µg/l. Methylene chloride results have not been adjusted to account for this background contamination. Other than methylene chloride, toluene, 1,1,1-trichloroethane, trichloroethene and tetrachloroethene were the only VOCs detected more than 50 percent of the time in the CSO samples. Volatile organic compound concentrations also varied from drainage area to drainage area. As with the toxic metal concentrations, the median concentrations for the volatile organics were lower than the average concentrations for those pollutants.

None of the eleven acid extractable organic pollutants were detected in the CSO samples collected in the Dexter @ Huntington, Ernest @ Allens, Branch, or Eustis drainage areas. Phenol was the most frequently detected acid extractable compound in the remaining five catchment areas (detected in seven of 11 CSO samples at an average concentration of 24 µg/l). The drainage area with the highest acid extractable pollutant concentrations was the Prairie drainage area. Phenol and 2,4-dimethyphenol were detected in all of the samples collected at this location; their average concentrations were 165 µg/ℓ and 111 µg/ℓ, respectively.

With the exception of bis(2-ethylhexyl)phthalate, which was detected in 81 percent of the CSO samples at average and median concentrations of 16 µg/l and 18 µg/l, respectively, base-neutral extractable organic pollutant occurrences were sporadic and those pollutants present had low concentrations when detected. The CSO total base-neutral pollutant average concentration was 21 µg/l.

The average concentrations of total solids and total suspended solids in CSOs were 376 mg/l and 273 mg/l, respectively. The mass of these pollutants is large because of the tremendous volume of wastewater that may be discharged as CSO. The CSO average BOD_5 and COD concentrations were 65 mg/l and 218 mg/l, respectively. Median values for all the conventional/nonconventional pollutants were much closer to the average values for each pollutant in comparison to the average and median concentrations for the toxic pollutants. Variation in sources of industrial wastewaters is suspected to be the reason for the differences in the toxic pollutant average and median concentrations.

Common to all pollutants detected in the CSO was a high degree of variability in concentration. Figure 6.1 presents the CSO concentrations by drainage area for selected pollutants. Pollutant concentrations in samples collected at the Michigan and Eustis regulators were the most consistent from storm to storm. This may be because the Eustis drainage area has no heavy industrial contribution (majority of area is light industrial, warehouse type land use) and the Michigan drainage area is dominated by commercial establishments with limited industrial dischargers.

As Figure 6.1 depicts, the pollutant concentrations in the CSO samples varied widely during the 22 storm events sampled. Most of the average CSO concentrations are elevated as a result of several high concentrations that skew the database. For example, the average CSO nickel concentration for all 22 storm events is 555 µg/ℓ. This average concentration is heavily biased by the three nickel concentrations observed at the Ernest @ Allens drainage area

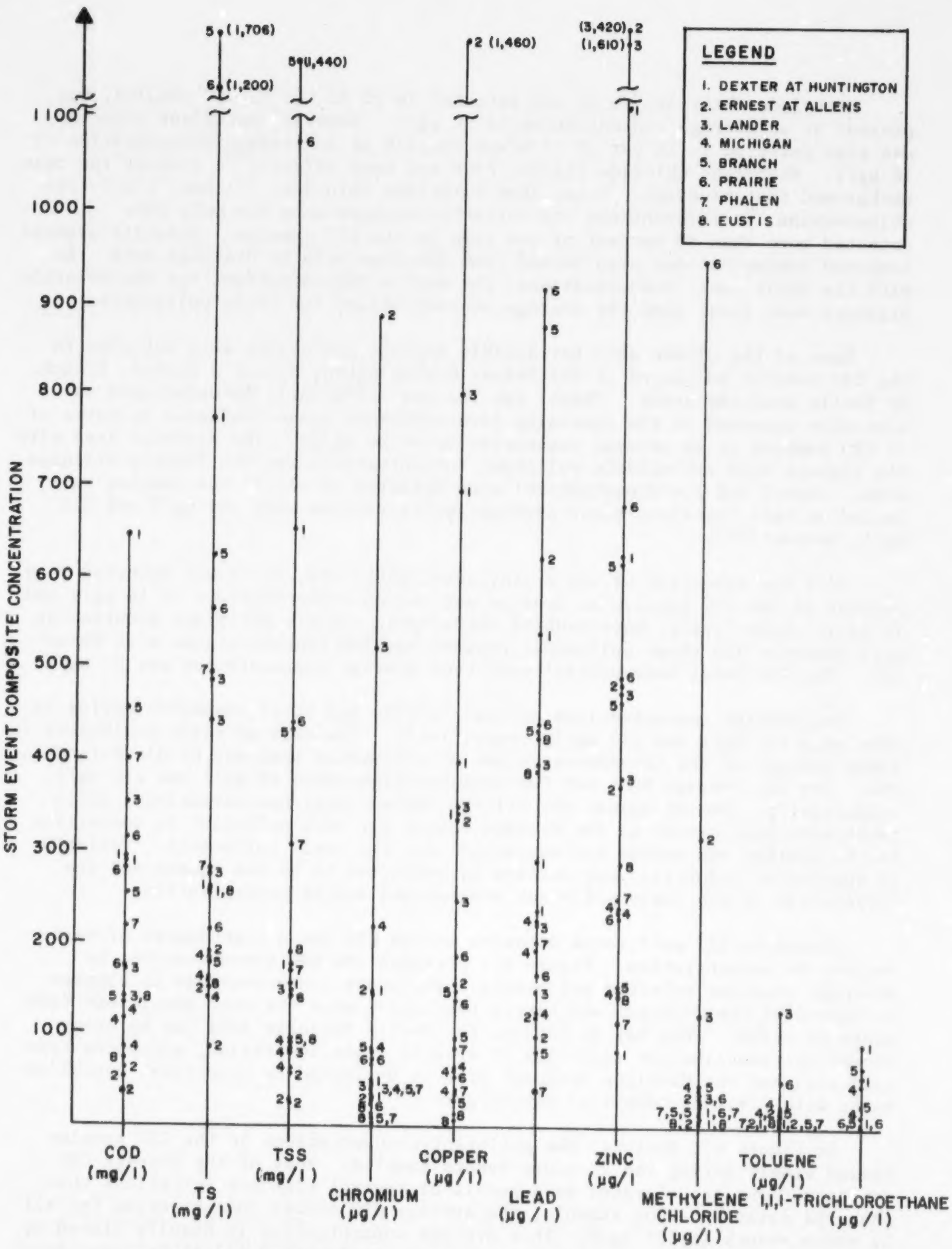

FIGURE 6.1 COMBINED SEWER OVERFLOW POLLUTANT CONCENTRATIONS BY DRAINAGE AREA

(7,200 μg/ℓ, 1,310 μg/ℓ, and 818 μg/ℓ). The CSO median concentration, which is a measure of the central tendency of a data array, was lower than the CSO average concentration throughout this study. In several instances, such as the example of nickel above, the median concentration is much lower than the average concentration (median CSO concentration for nickel was 81 μg/ℓ compared to an average CSO concentration of 555 μg/ℓ).

One way to observe the relative skewness of the data is to evaluate the database for a given percentile. Figure 6.2 presents the ranges, averages, and medians of all concentrations within the 10th to 90th percentile for the pollutants listed in Figure 6.1. This analysis eliminates the two highest and two lowest concentrations which, in general, bias in a positive direction the average concentrations. By eliminating the highest two values for each pollutant, the average values tend to approach the respective median concentrations.

One objective of this CSO study is to estimate the impact of toxic pollutants in CSOs on a national level. Using the results of the CSO study, the amount of priority toxic pollutants discharged in CSOs nationally can be estimated. Many factors influence the discharge of toxic pollutants in CSOs including land use, industries within the drainage area, size of the drainage area, intensity of the storm event, and implementation of pretreatment programs. For these reasons, projections on a nationwide basis are estimates that should only be used for comparative analysis, such as a comparison of the mass of toxic pollutants discharged in CSOs to the estimated mass of toxic pollutants discharged in POTW effluents.

Using results of this CSO study, pollutant indices, which were normalized on a mass per acre per inch of rain basis, were calculated for the 11 priority toxic pollutants detected 50 percent of the time or greater in CSOs and for selected conventional/nonconventional pollutants. These indices are presented in Table 6.4. Assuming a total combined sewer area of 2,823,800 acres and an average annual rainfall of 33.4 inches (2), annual pollutant loadings were calculated using the calculated pollutant indices. Table 6.5 summarizes the nationwide CSO toxic pollutant mass projections based on the analytical results from this study. Also presented in Table 6.5 are the nationwide projections for BOD_5, TSS, and lead as estimated by the 1982 Needs Survey.

RUNOFF ANALYSIS

During this study, 21 composite runoff samples were collected. Composite periods extended from the inception of a storm event until runoff ceased. Subsamples were collected at equal time intervals and composited to form a single sample per storm event per catchment area. Three runoff samples were collected in each of the eight catchment areas with the exception of the Branch, Eustis, and Phalen Creek locations where two samples per location were collected. Each of the 21 samples represents a different combination of circumstances. For example, the dry weather period between storm events influences pollutant concentrations. Traffic volume and street cleaning practices also have a direct bearing on runoff quality. Land use, slope of the drainage area, percent of the drainage area that is impervious, intensity of a storm event, and volume of rainfall all affect the runoff quantity from a given drainage area. Pollutant transport mechanisms further complicate a runoff

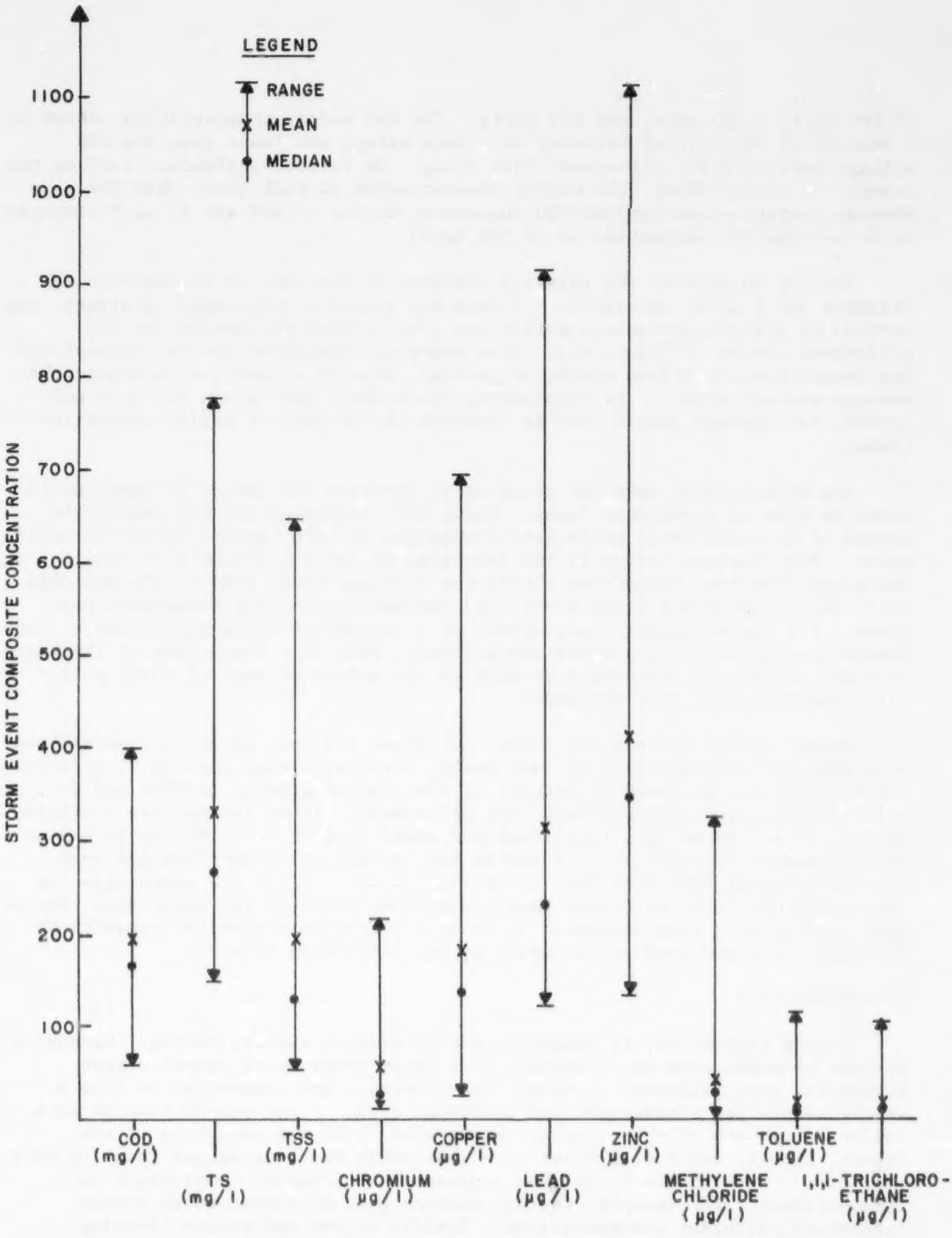

FIGURE 6.2 COMBINED SEWER OVERFLOW POLLUTANT CONCENTRATIONS FOR THE 10th TO 90th PERCENTILE.

TABLE 6.4 COMBINED SEWER OVERFLOW POLLUTANT INDICES

	POUNDS PER ACRE PER INCH OF RAINFALL		
Pollutant	Average[1]	Maximum	Minimum
Priority Pollutants			
Metals:			
Zinc	26×10^{-3}	472×10^{-3}	2.8×10^{-3}
Copper	15×10^{-3}	240×10^{-3}	$<0.4 \times 10^{-3}$
Chromium	4.4×10^{-3}	150×10^{-3}	$<0.2 \times 10^{-3}$
Lead	20×10^{-3}	75×10^{-3}	$<1.7 \times 10^{-3}$
Nickel	17×10^{-3}	$1{,}180 \times 10^{-3}$	$<0.9 \times 10^{-3}$
Volatiles:			
Methylene Chloride	4.0×10^{-3}	54×10^{-3}	0
Toluene	0.7×10^{-3}	37×10^{-3}	0
1,1,1-Trichloroethane	1.4×10^{-3}	32×10^{-3}	0
Trichlorethene	4.2×10^{-3}	178×10^{-3}	0
Tetrachloroethene	2.4×10^{-3}	32×10^{-3}	0
Base-Neutrals:			
Bis(2-ethylhexyl)phthalate	0.5×10^{-3}	3.10×10^{-3}	0
Conventional Pollutants			
Biochemical Oxygen Demand (5-day)	3.4	36	0.6
Chemical Oxygen Demand	11.0	102	1.8
Total Solids	22.0	143	3.4
Total Suspended Solids	12.0	65	1.6

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[1] Indices are calculated using data in the 10th to 90th percentile of the database.

TABLE 6.5 PROJECTED COMBINED SEWER OVERFLOW MASS DISCHARGED NATIONWIDE

Pollutant	CSO[1] pounds/year	CSO[2] pounds/year
Priority Pollutants		
Metals:		
Zinc	1,937,000	
Copper	1,114,000	
Chromium	330,000	
Lead	1,491,000	2,010,000
Nickel	1,261,000	
Volatiles:		
Methylene Chloride	300,000	
Toluene	53,000	
1,1,1-Trichlorethane	105,000	
Trichloroethene	315,000	
Tetrachloroethene	180,000	
Base-Neutrals:		
Bis(2-ethylhexyl)phthalate	38,000	
Conventional Pollutants		
Biochemical Oxygen Demand (5-day)	253,000,000	306,000,000
Chemical Oxygen Demand	848,400,000	
Total Solids	1,667,000,000	
Total Suspended Solids	871,000,000	5,310,000,000

[1] Based on an area served by combined sewers of 2,823,800 acres, an average annual rainfall of 33.4 inches and pollutant indices in Table 6.4.

[2] From 1982 Needs Survey

analysis.

As previously mentioned, the most prevalent priority pollutant metals in the runoff were zinc, lead, copper, and chromium. Methylene chloride and bis(2-ethylhexyl)phthalate were also detected in a majority of runoff samples but at lower concentrations than those metals. The nonconventional metals aluminum and iron were detected in all 22 runoff samples analyzed and titanium was present in 81 percent of the runoff samples. Generally, the concentrations for these three nonconventional metals were greater in the runoff than in the CSF samples.

Figure 6.3 presents the concentrations of selected pollutants in the runoff samples by drainage area. A "clustering" of pollutant concentrations by location can generally be observed. This pattern illustrates the importance of site-specific factors in determining runoff characteristics. When compared to the CSO concentrations shown in Figure 6.1, runoff pollutant concentrations fall within a smaller range of values. This is most likely due to the inclusion of highly variable industrial wastewater in CSOs and the lack of it in runoff. Averages, medians and ranges of runoff pollutant concentrations between the 10th and 90th percentile for selected pollutants are presented in Figure 6.4. Table 6.6 summarizes the concentrations of the pollutants listed in Figure 6.4 and the concentrations for several other pollutants.

Runoff concentrations for the conventional pollutants COD, BOD_5, TS and TSS are also presented in Table 6.6. In comparison to the COD of the wastewater samples collected during dry weather periods (average COD of 608 mg/ℓ), the runoff COD (80 mg/l) is small. As expected, the biologically oxidizable organic material present in the runoff is less appreciable than that of the COD; five day biochemical oxygen demand values were less than 30 mg/ℓ for each of 21 samples. The average total solids and total suspended solids runoff concentrations of 188 mg/ℓ and 108 mg/ℓ, respectively, are significant in light of the tremendous volumes associated with urban runoff.

Toxic and nonconventional metals found in the runoff samples include chromium, copper, lead, zinc, aluminum, iron, and titanium. With the exception of titanium, which is used as both a white paint pigment and in whitening paper in the form of titanium dioxide, each of these elements is associated with vehicular traffic. Lead compounds used as anti-knock additives in gasoline are released into the atmosphere in automobile exhaust fumes. These compounds and to a lesser extent, the lead compounds produced by burning coal, may precipitate to the land surface or be washed from the air by rain and enter the sewer in the runoff. Zinc is in motor oil, transmission fluid, rubber tires, and concrete; copper is found in antifreeze, rubber tires, and brake linings; aluminum is used extensively in building supplies and various automobile components; iron is abundant as a structural element; and chromium is associated with many structural alloys and plated parts.

While the preceding analysis details the concentration of various pollutants present in runoff, a more accurate assessment of runoff pollutants normalizes the pollutant mass on a per unit area per inch of rainfall basis. Such an evaluation was conducted for the two priority pollutants detected most often and at the highest concentrations (lead and zinc). The graphs in Figures 6.5 and 6.6 demonstrate that the zinc and lead mass per acre of drainage area

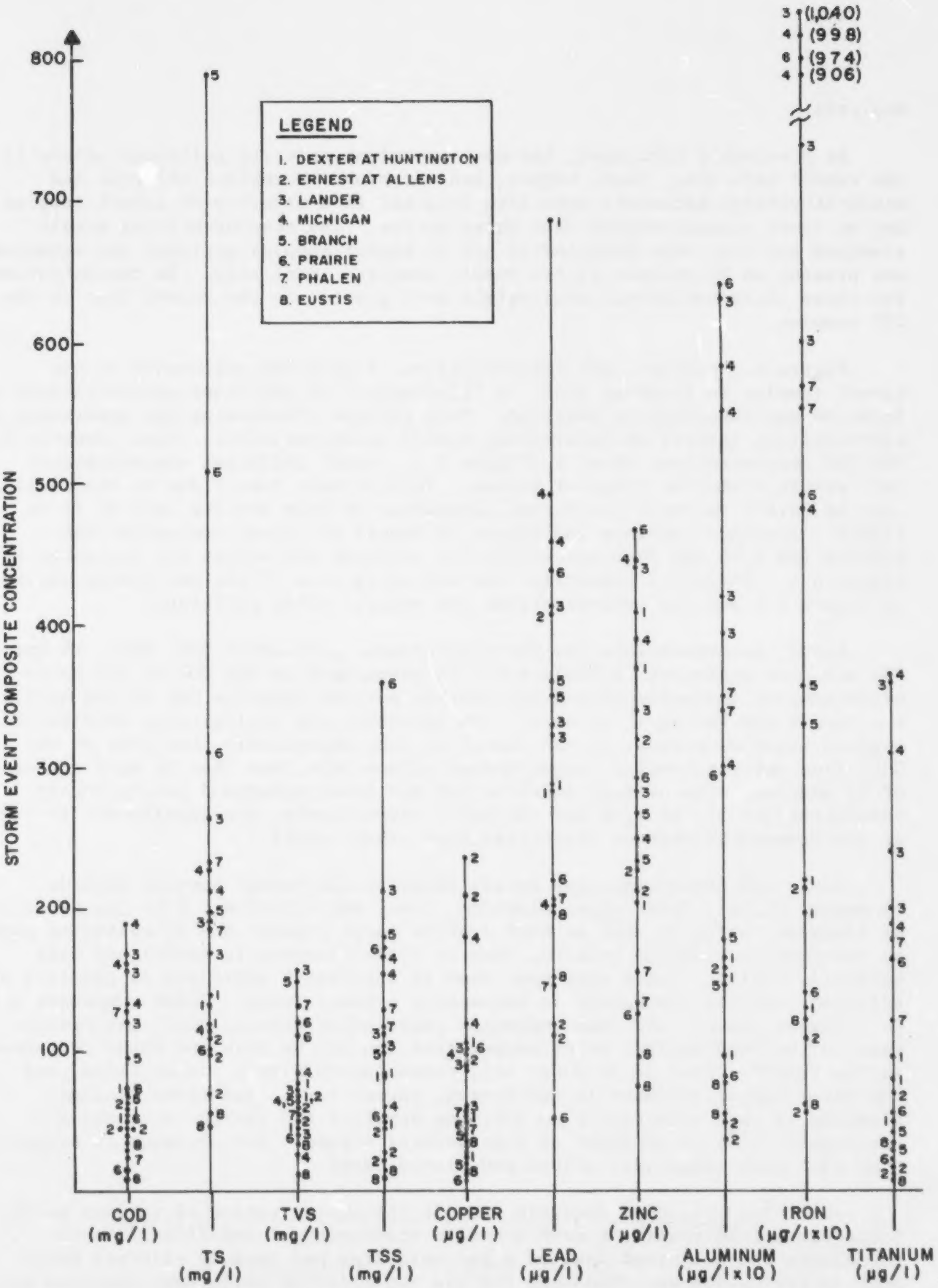


FIGURE 6.3 RUNOFF POLLUTANT CONCENTRATIONS BY DRAINAGE AREA

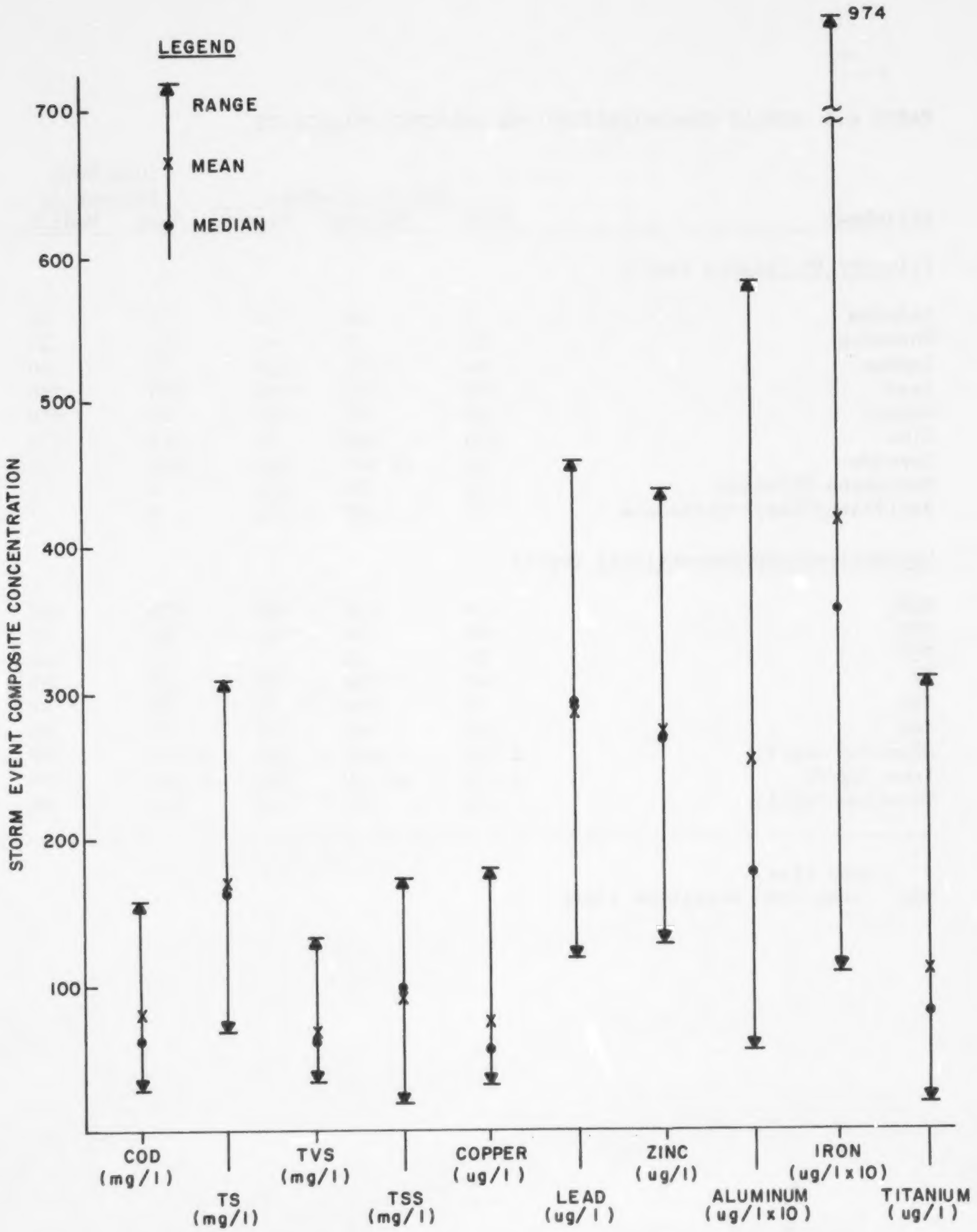


FIGURE 6.4 RUNOFF POLLUTANT CONCENTRATIONS FOR THE 10th TO 90th PERCENTILE

TABLE 6.6 RUNOFF CONCENTRATIONS FOR SELECTED POLLUTANTS

Pollutant	Entire Database			10th-90th Percentile	
	Mean	Maximum	Minimum	Mean	Median
Priority Pollutants (μg/l)					
Cadmium	9	26	<5	8	<5
Chromium	22	53	<4	21	24
Copper	84	238	<20	75	60
Lead	297	683	<120	288	290
Nickel	89	525	<50	66	<50
Zinc	274	462	74	275	272
Cyanide	560	11,900	<20	<20	<20
Methylene Chloride	32	350	<DL	9	9
Bis(2-ethylhexyl)phthalate	17	200	<DL	8	7
Conventional/Nonconventional (mg/l)					
BOD_5	<30	<30	<30	<30	<30
COD	<85	190	<50	80	60
TOC	24	52	12	23	23
TS	188	788	50	169	169
TVS	74	156	11	70	59
TSS	108	365	15	97	99
Aluminum (μg/ℓ)	2,730	6,630	388	2,560	1,780
Iron (μg/ℓ)	4,430	10,400	592	4,200	3,580
Titanium (μg/ℓ)	126	360	<12	112	80

< - Less than
<DL - Less than detection limit

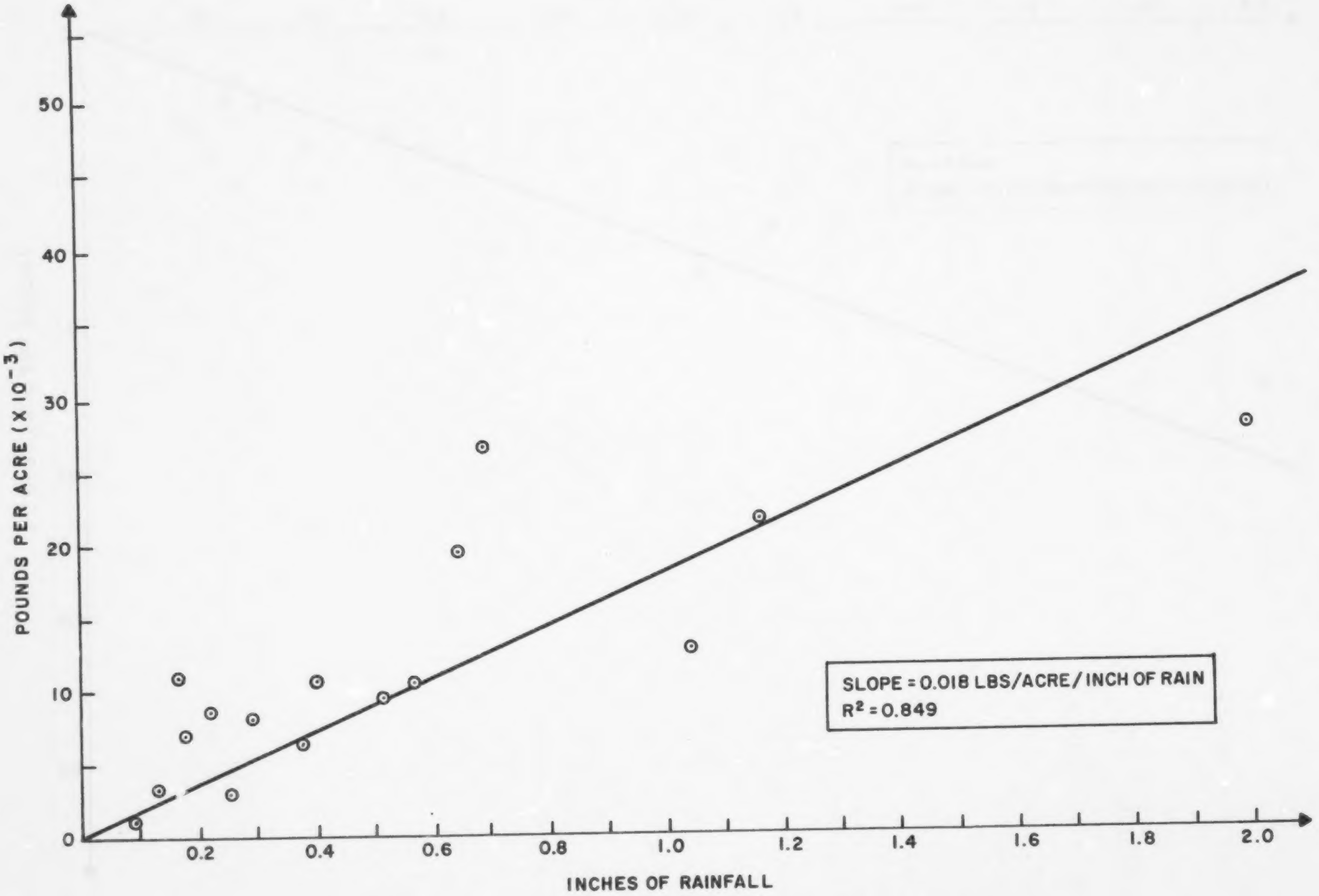


FIGURE 6.5 LEAD MASS PER UNIT AREA VERSUS RAINFALL.

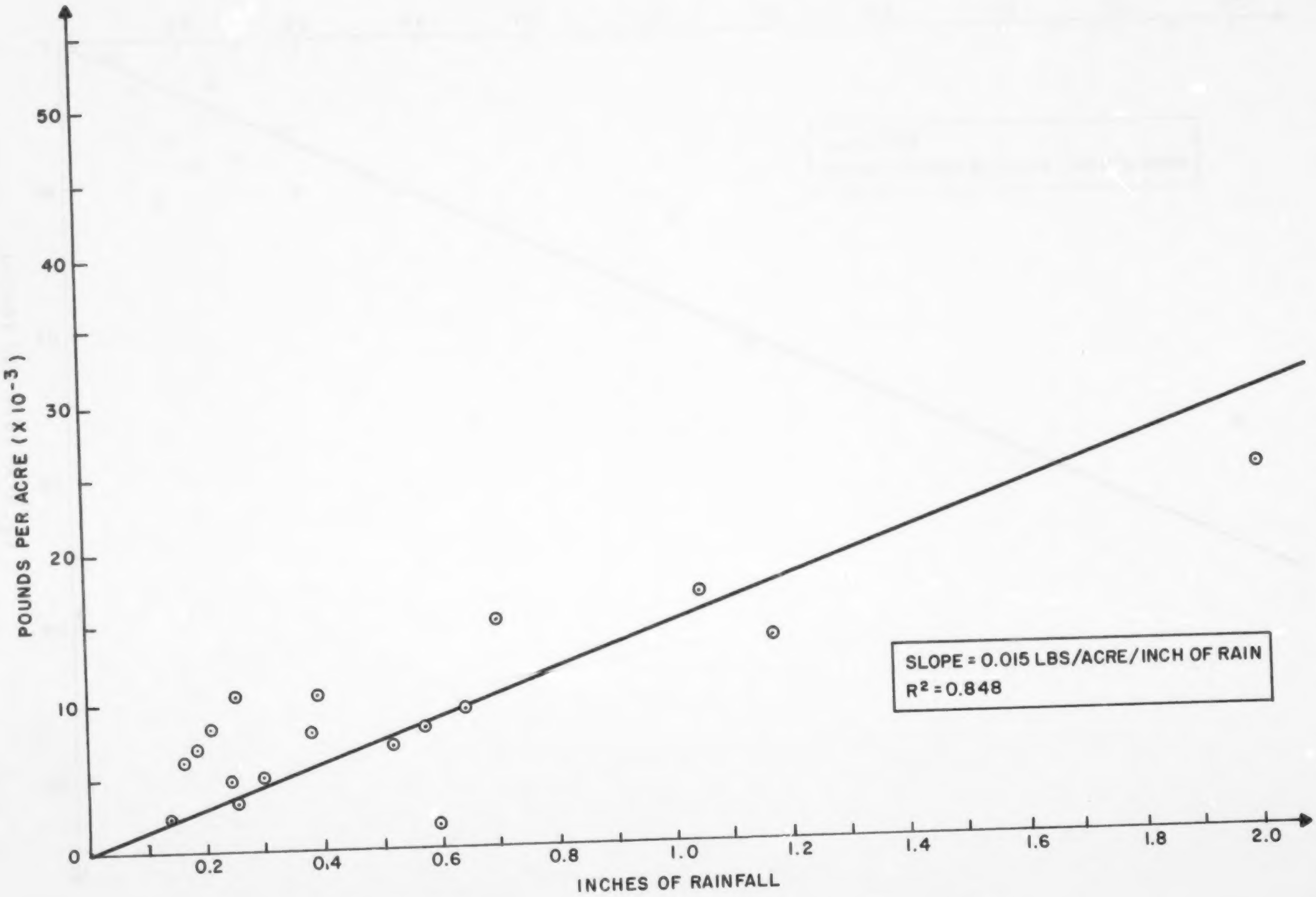


FIGURE 6.6 ZINC MASS PER UNIT AREA VERSUS RAINFALL.

have a linear relationship to the amount of rainfall. Correlation coefficients were 0.849 and 0.848 for lead and zinc, respectively, and average pounds per acre per inch of rainfall were 0.018 and 0.015. While data for storms in excess of 1.0 inch of rainfall were limited during this study, the data that are available suggest that there may be a reduction of pollutant mass per inch of rain. This phenomenon is likely the result of pollutant availability being reduced during the latter half of larger storm events.

A careful examination of the individual data points was performed to determine relationships between antecedent dry weather periods and storm intensity in comparison to pollutant mass per acre per inch of rainfall. It was anticipated that the greatest pollutant mass per acre per inch of rainfall would correspond to high intensity storm events preceded by a substantial dry weather period. No correlation was found, however, between either rainfall intensity or antecedent dry weather conditions and pollutant mass per acre per inch of rainfall. Antecedent conditions in particular did not have a direct bearing on the lead and zinc mass. High intensity storms in general generated a larger pollutant mass per unit area per inch of rain. However, this trend was not observed for several catchment areas, such as the Lander drainage area.

Although the pollutant mass per acre per inch of rainfall for lead and zinc do not appear to be empirically related to storm intensity and antecedent conditions, the individual concentrations for lead and zinc by storm event do exhibit a similarity to each other. These pollutant patterns suggest that the source of pollutants, in this case probably vehicular traffic, is the same for both lead and zinc.

Mass yield per acre of drainage area versus rainfall graphs for COD and TS were also developed. As with lead and zinc, COD and TS yields appear to follow a linear relationship with rainfall (i.e., the more rain the more COD and TS discharged) although the scatter of the data points is greater (linear correlation coefficients of 0.649 for COD and 0.790 for TS). The COD and TS mass per acre of drainage area versus rainfall graphs are presented in Figures 6.7 and 6.8, respectively.

COMPARISON OF DRY WEIGHT POLLUTANT CONCENTRATIONS

The analyses to this point have presented pollutant concentrations on a "wet basis" (i.e., mg/ℓ or µg/ℓ for a selected pollutant). Another analysis, which is a convenient way to compare waste streams with diversified residue concentrations, is the presentation of pollutant concentrations on a "dry weight basis" [i.e., milligrams (mg) of pollutant per kilogram (kg) of residue (or solid material) in a sample]. This evaluation assumes a total solids common denominator in lieu of the unit volume of wastewater denominator assigned for "wet" concentrations. Dry weight concentrations reduce the significance of dilution on certain waste streams, and provides information on the source of pollutants and the characteristics of the various waste streams. A comparison of the dry weight concentrations (mg pollutant/kg TS) of selected pollutants in runoff, CSO, and dry weather background samples is presented in Table 6.7.

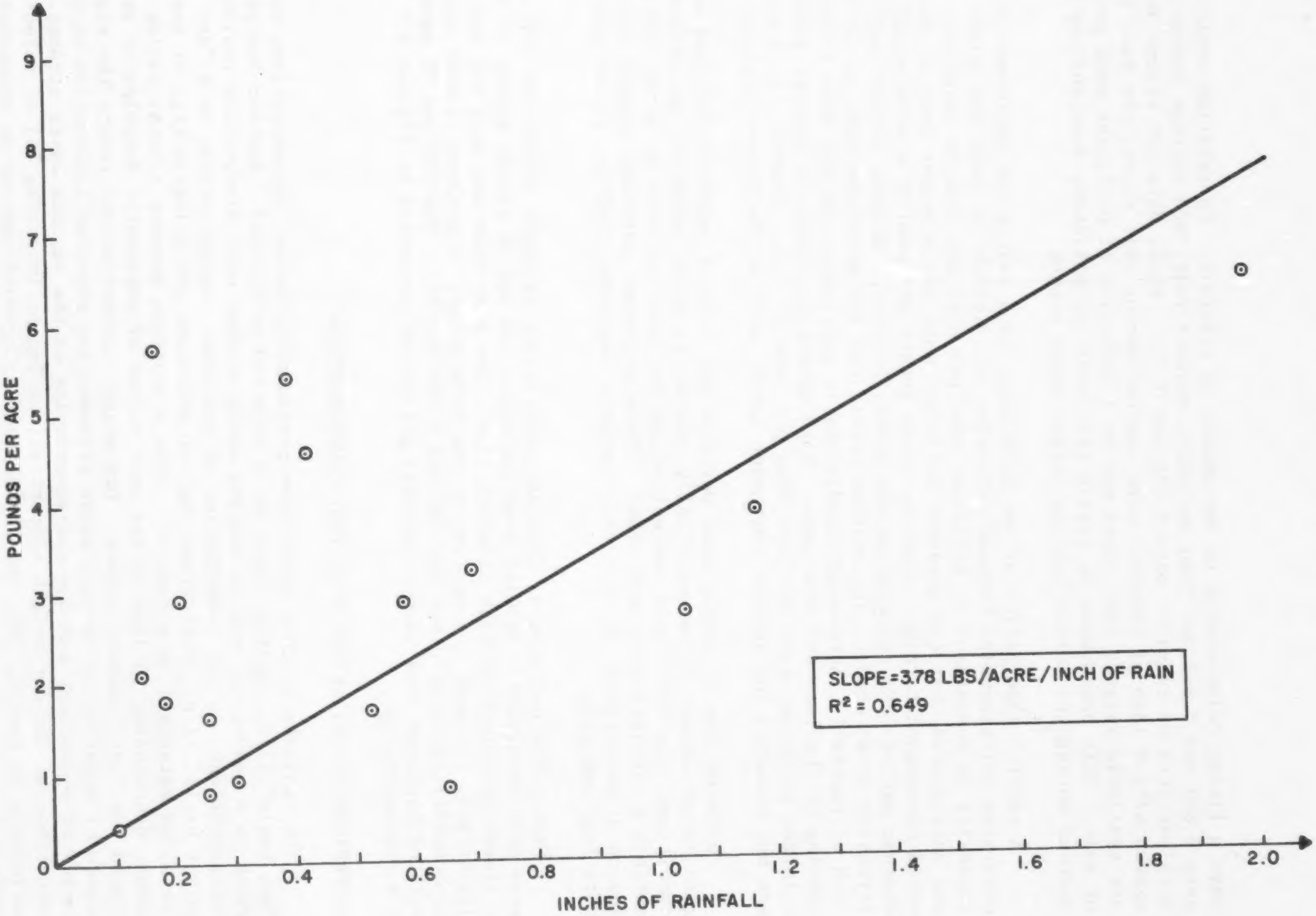


FIGURE 6.7 CHEMICAL OXYGEN DEMAND MASS PER UNIT AREA VERSUS RAINFALL.

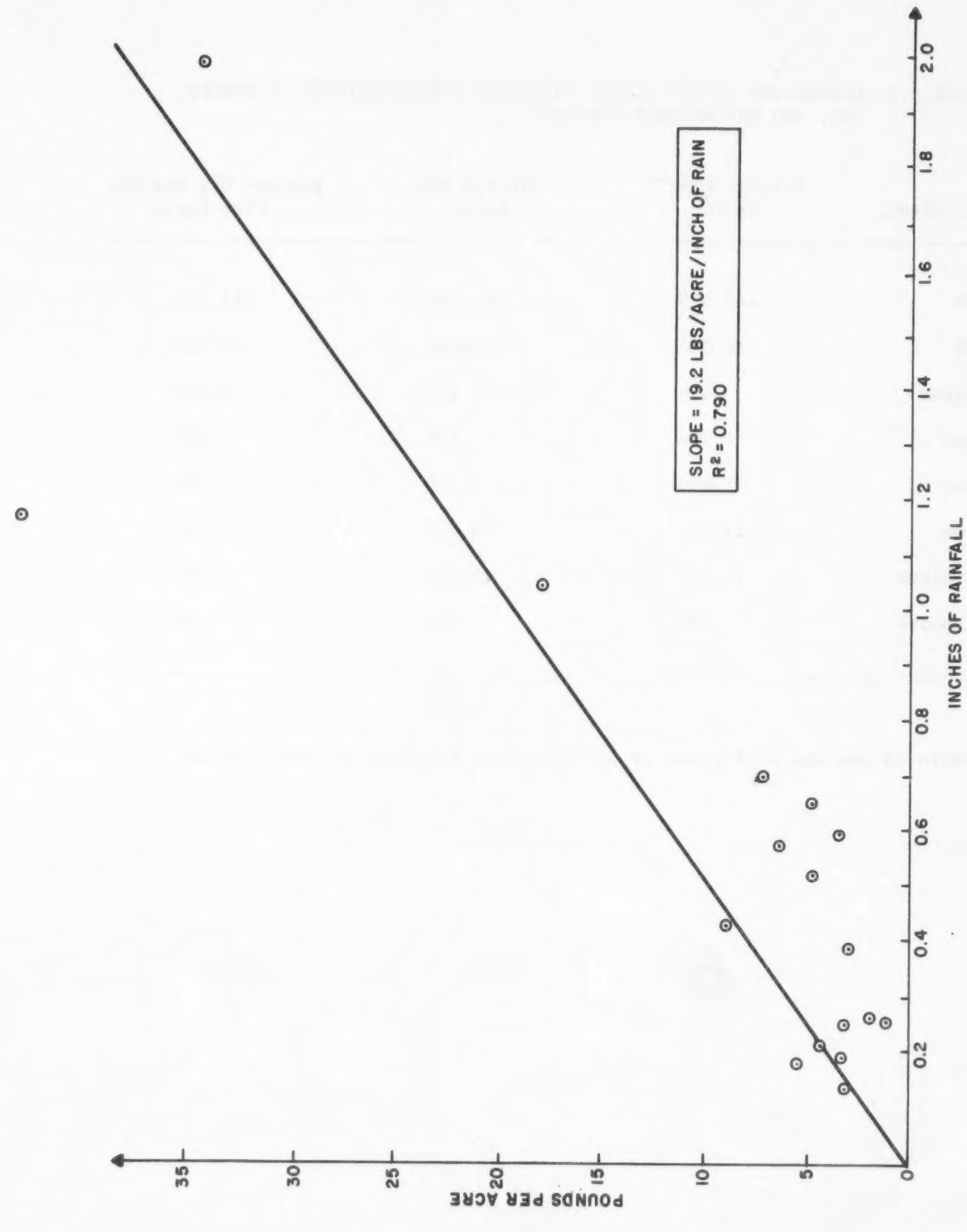


FIGURE 6.8 TOTAL SOLIDS MASS PER UNIT AREA VERSUS RAINFALL.

TABLE 6.7 COMPARISON OF DRY WEIGHT POLLUTANT CONCENTRATIONS IN RUNOFF, CSO, AND DRY WEATHER SAMPLES*

Pollutant	Average Runoff Ratio	Average CSO Ratio	Average Dry Weather Flow Ratio
COD	473,000	594,000	951,000
TVS	414,000	430,000	358,000
Copper	440	580	1,150
Lead	1,700	920	220
Zinc	1,600	1,200	1,000
Iron	24,900	14,700	3,500
Aluminum	16,200	12,000	1,600
Titanium	750	340	45

*Ratio values are milligrams of pollutant per kilogram of total solids.

The concentrations of lead, zinc, iron, aluminum, and titanium are greatest in the runoff samples, and the concentrations of COD and copper are highest in the dry weather wastewater samples. Because runoff and dry weather wastewater are both components of CSO, Table 6.7 suggests that runoff significantly contributes to lead, zinc, iron, aluminum, and titanium in CSO. In contrast, COD and copper contributions from dry weather background sources are much more prominent than contributions from runoff. An interesting observation in Table 6.7 is that the total volatile solid (TVS) concentration for CSOs is greater than either the runoff or dry weather TVS concentrations. This increase is volatile material (i.e., matter which is combustible at 550°C) may be the result of settled volatile material in the collection system being resuspended during wet weather, high flow conditions. A more detailed analysis of the source of pollutants is presented in the mass balance analysis section.

COMBINED SEWER MASS BALANCE

Mass balances for each of the catchment areas were calculated for priority toxic pollutants and for selected conventional/nonconventional pollutants. Results of the mass balances were used to determine the source of pollutants in CSF and the fate of those pollutants (i.e., either discharged to a POTW or in the CSO). The fate of the pollutants was determined by calculating the amount of pollutants in the CSF and in the CSO. The difference in masses for these two flows is the amount discharged to a POTW.

For this analysis, if a priority toxic metal concentration was reported as less than the analytical detection limit, the concentration was assumed to equal the detection limit. Priority toxic organic pollutant concentrations reported as not detected were assigned a zero concentration. This editing rule does not affect the quantity of the organic pollutant mass since all organic concentrations are reported as an absolute value or as not detected. This editing rule also does not severely impact the quantity of the pollutant mass for the metals zinc, lead, nickel, chromium and copper since absolute values were reported for the majority of the samples included in the mass balance analysis. The total toxic metal mass (which includes the infrequently detected metals silver, thallium, arsenic, beryllium, cadmium, antimony, mercury and selenium) would be lower (approximately six to 10 percent lower than the reported mass) if "less than" concentrations were assigned a zero concentration in lieu of the detection limits assumed.

Source of Pollutants in Combined Sewer Flow--

For the combined sewer mass balance analysis, the influent mass to the regulator chamber is equal to the combined sewer flow pollutant mass. As illustrated in Figure 6.9, the combined sewer flow pollutant mass is comprised of several components. The background pollutant mass is the mass associated with residential, commercial, and industrial wastewater and represents the dry weather baseline mass. Wet weather sources of pollutants include precipitation, runoff, and resuspension of pollutants that accumulate in the collection system. As discussed earlier, precipitation did not constitute a major source of any toxic pollutants.

Background, runoff, resuspension, and CSF toxic pollutant masses were quantified for the 22 storm events sampled. CSF, background and runoff toxic

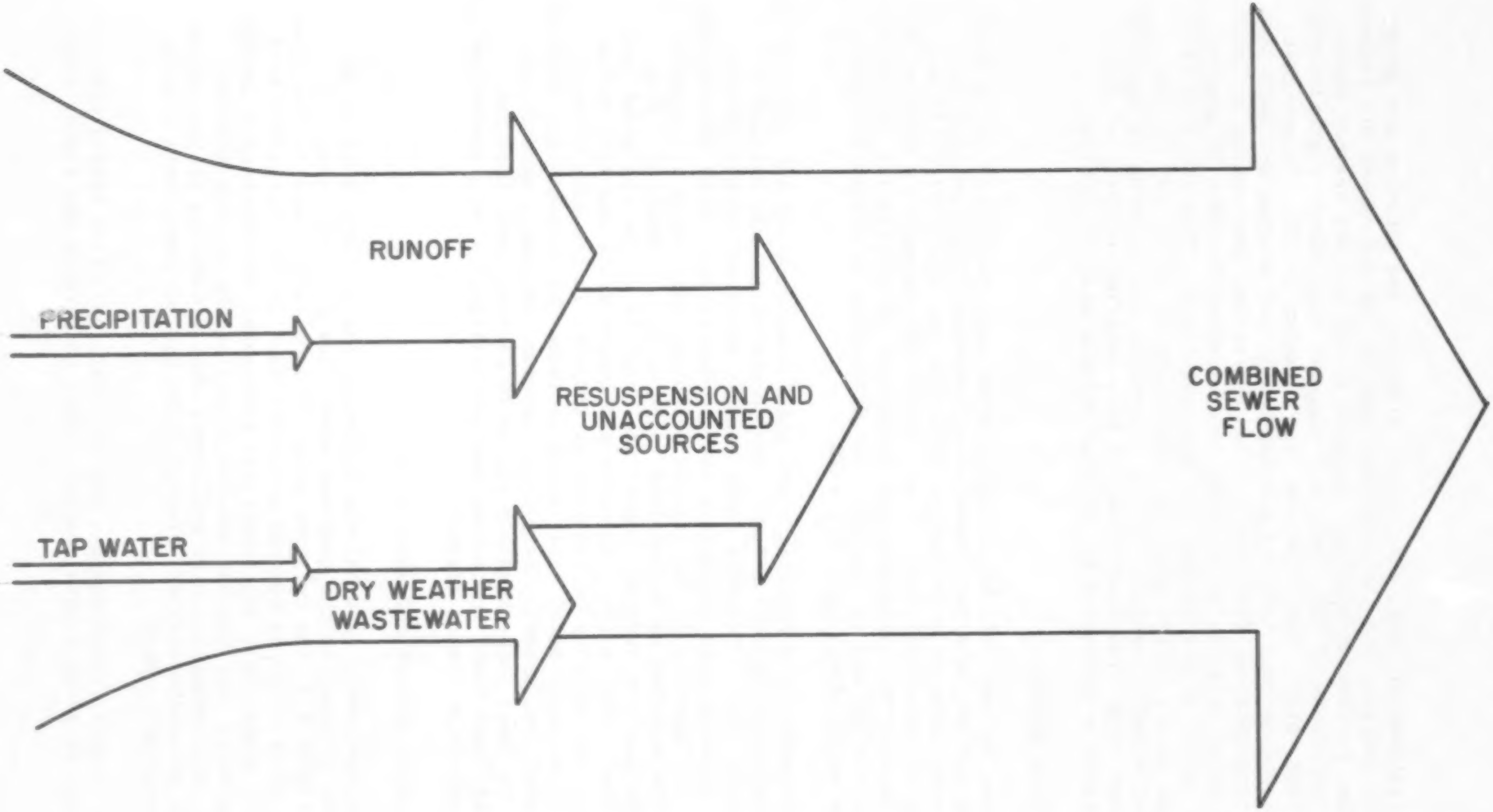

RUNOFF
PRECIPITATION
RESUSPENSION AND UNACCOUNTED SOURCES
COMBINED SEWER FLOW
TAP WATER
DRY WEATHER WASTEWATER

FIGURE 6.9 SOURCE OF POLLUTANTS IN COMBINED SEWER FLOWS

pollutant masses were calculated based on observed flow rates and analytical results of samples collected. Resuspension toxic pollutant masses were estimated as the difference between the CSF mass and the sum of the background and runoff masses.

A study of the source of the five most prevalent toxic metals (zinc, lead, copper, nickel and chromium) in CSFs was conducted. Figures 6.10 through 6.14 present these results graphically, and Tables 6.8 through 6.12 summarize these results. These results are average mass discharges per storm event. For example, the average pounds of zinc per storm event in the CSF for the three storm events sampled at the Dexter @ Huntington location was 7.8 pounds. Of that 7.8 pounds, 1.3 pounds are from background sources, 1.7 pounds originate in runoff, and the remaining 4.8 pounds are assumed to be a resuspension of settled material from the sewers. Any systematic bias (such as analytical problems, field errors, or unaccounted sources) existing in this source analysis is accounted for in the "resuspension mass."

Zinc and lead were the priority pollutants present in the CSF in the greatest quantity. The primary source of each of these elements is runoff. This is apparent by observing Figures 6.10 and 6.11 which detail the sources of zinc and lead, respectively. Runoff sources account for over 57 percent of the CSF zinc mass and 89 percent of the CSF lead mass. The ratio of the zinc background pollutant mass to the zinc resuspension mass was fairly constant for each drainage area. With the exception of the Michigan and Phalen drainage areas (which had little resuspension of zinc), for each estimated pound of zinc that was present during a storm event as a result of normal dry weather sources, about four pounds of zinc were resuspended from the collection system.

Copper was the third most prevalent priority pollutant detected in CSF, although present at much lower levels (142 pounds total during this study) compared to zinc (301 pounds) and lead (215 pounds). Copper resuspension sources account for about 54 percent of the CSF copper mass (Figure 6.12). Similar to zinc, the ratio of copper background pollutant sources to copper resuspension sources was fairly constant (about 2.5 pounds of copper is estimated to be resuspended from the collection system for each pound of copper in the dry weather background flow).

Nickel was the most site-specific of the toxic elements. Evident in Figure 6.13 is the large contribution of nickel in the CSF samples in relation to the small size of the drainage areas at the Ernest @ Allens (65 acres), Dexter @ Huntington (300 acres) and Lander (500 acres) locations. The Ernest @ Allens CSF samples in particular had excessive nickel concentrations. The electroplating industry dominates the Ernest @ Allens drainage area, and to a lesser extent is present in the Dexter @ Huntington and Lander drainage areas.

Chromium was the fifth most prevalent toxic element in the CSF. Resuspension masses are estimated to be twice as large as both runoff and dry weather masses (See Figure 6.14).

Total priority toxic metals and priority toxic organic pollutant masses for each of the eight drainage areas are presented in Figure 6.15. These masses are the average pounds per storm event of toxic metals and toxic organic pollutants in the CSF. Average toxic metals mass in CSF ranged from 115 pounds

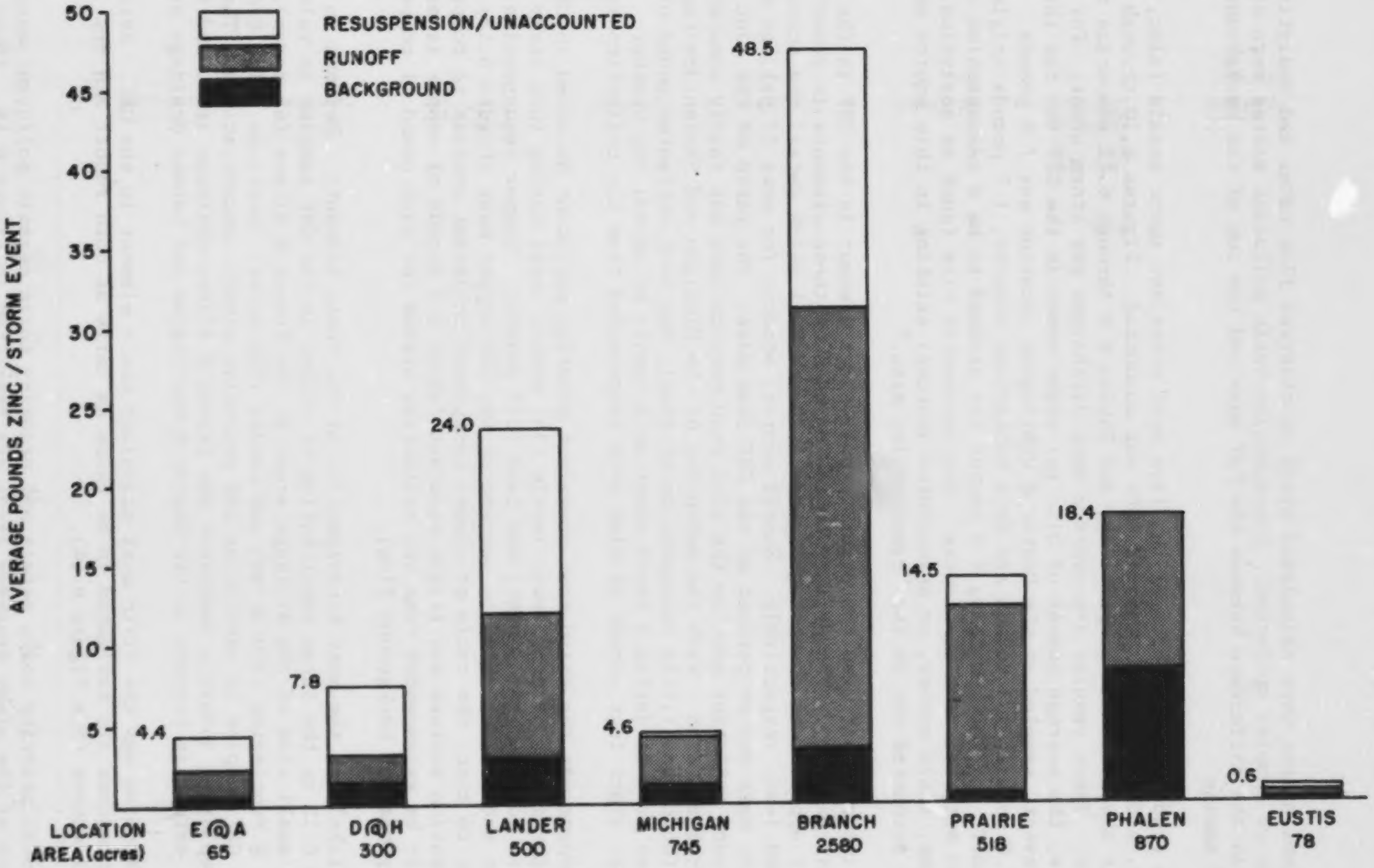


FIGURE 6.10 SOURCE OF ZINC IN COMBINED SEWER FLOW

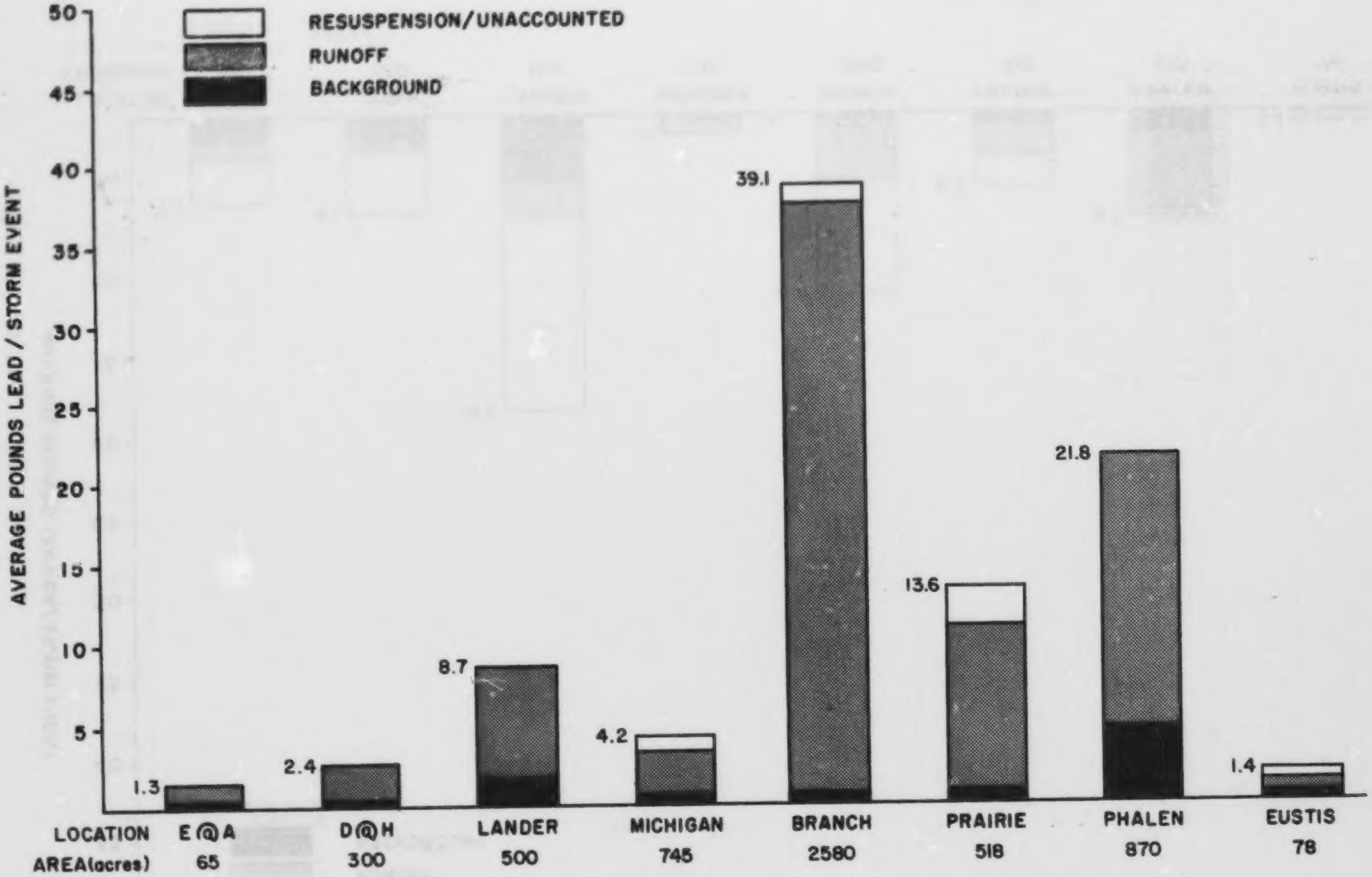


FIGURE 6.11 SOURCE OF LEAD IN COMBINED SEWER FLOW

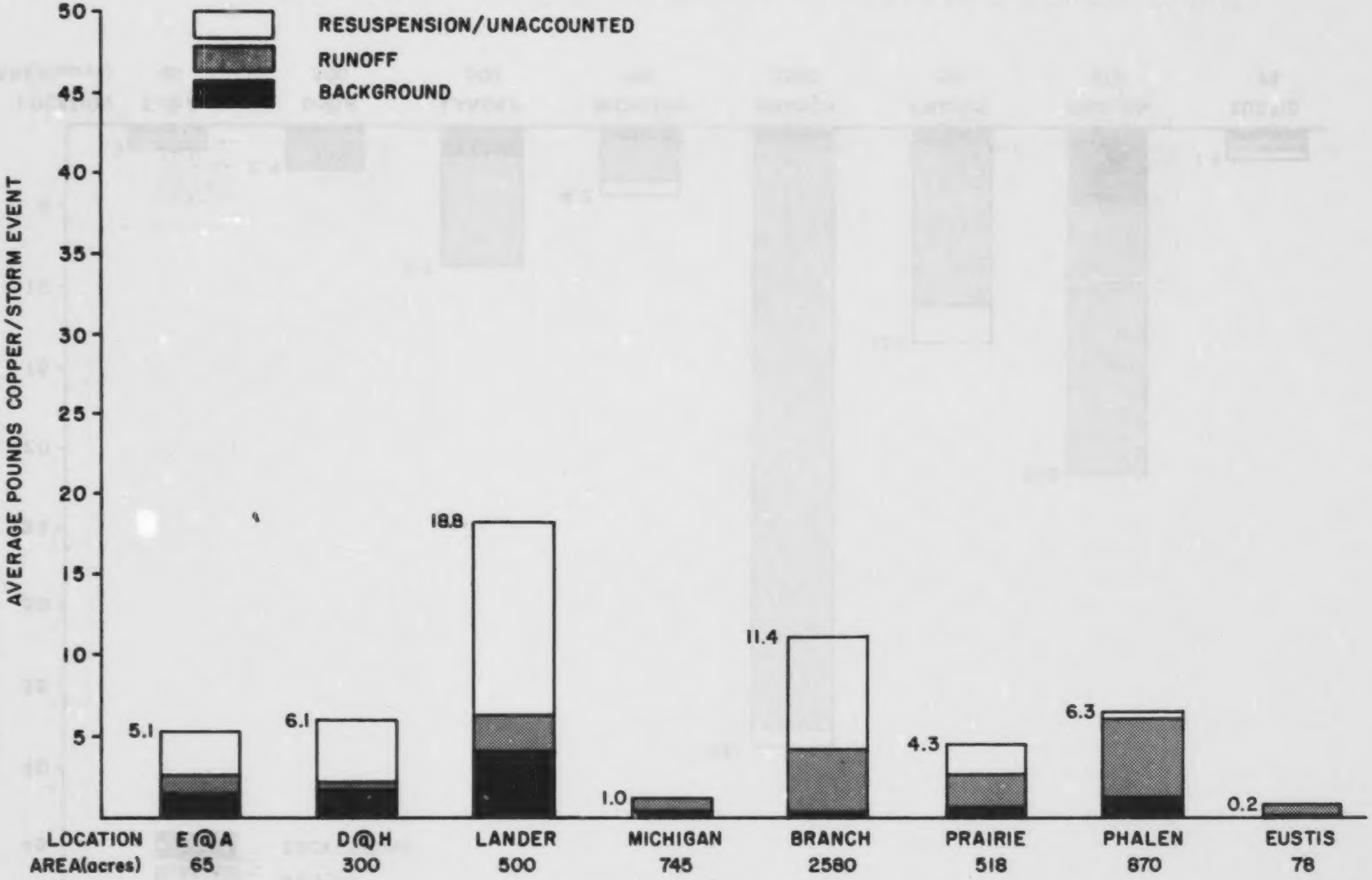


FIGURE 6.12 SOURCE OF COPPER IN COMBINED SEWER FLOW

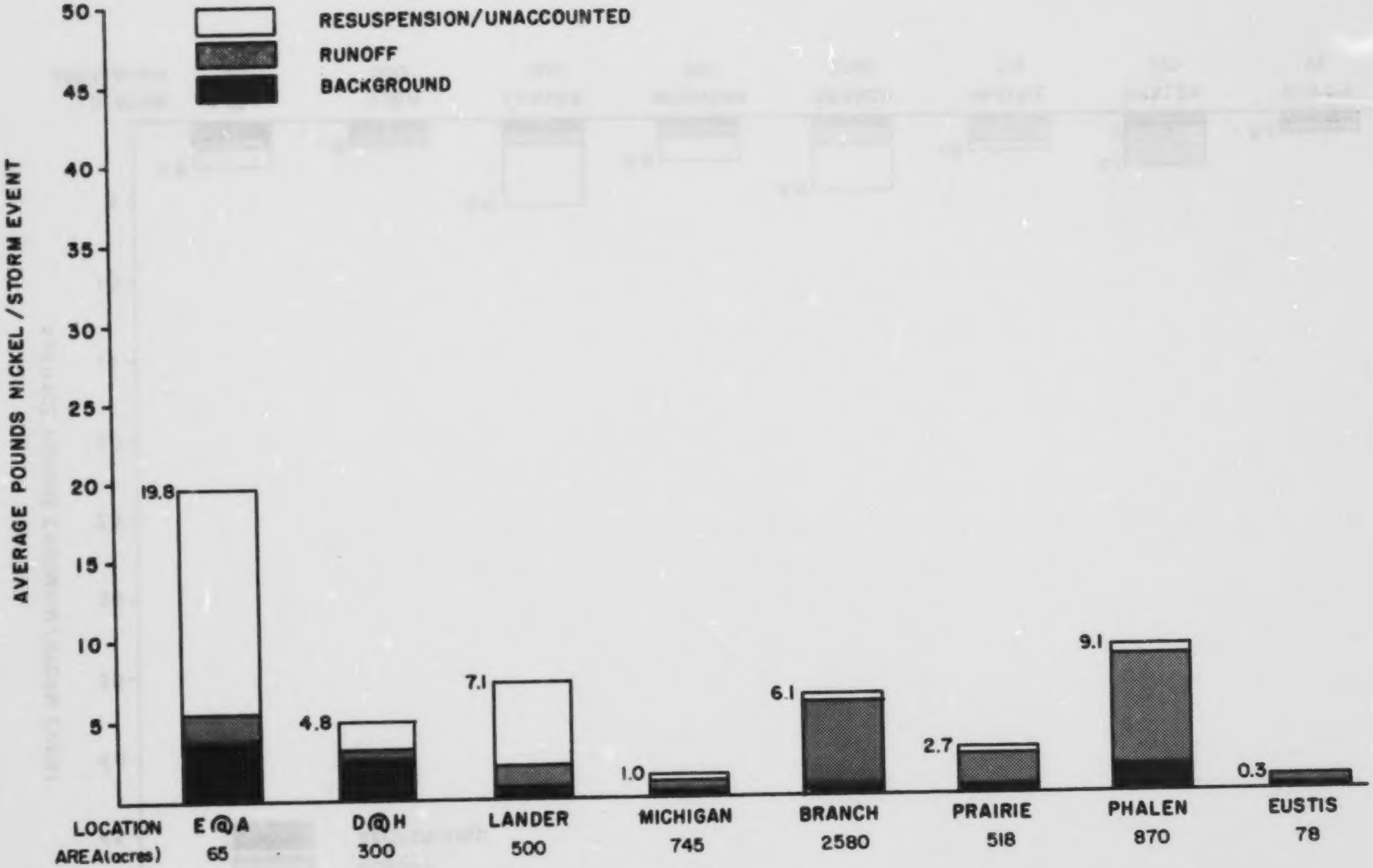


FIGURE 6.13 SOURCE OF NICKEL IN COMBINED SEWER FLOW

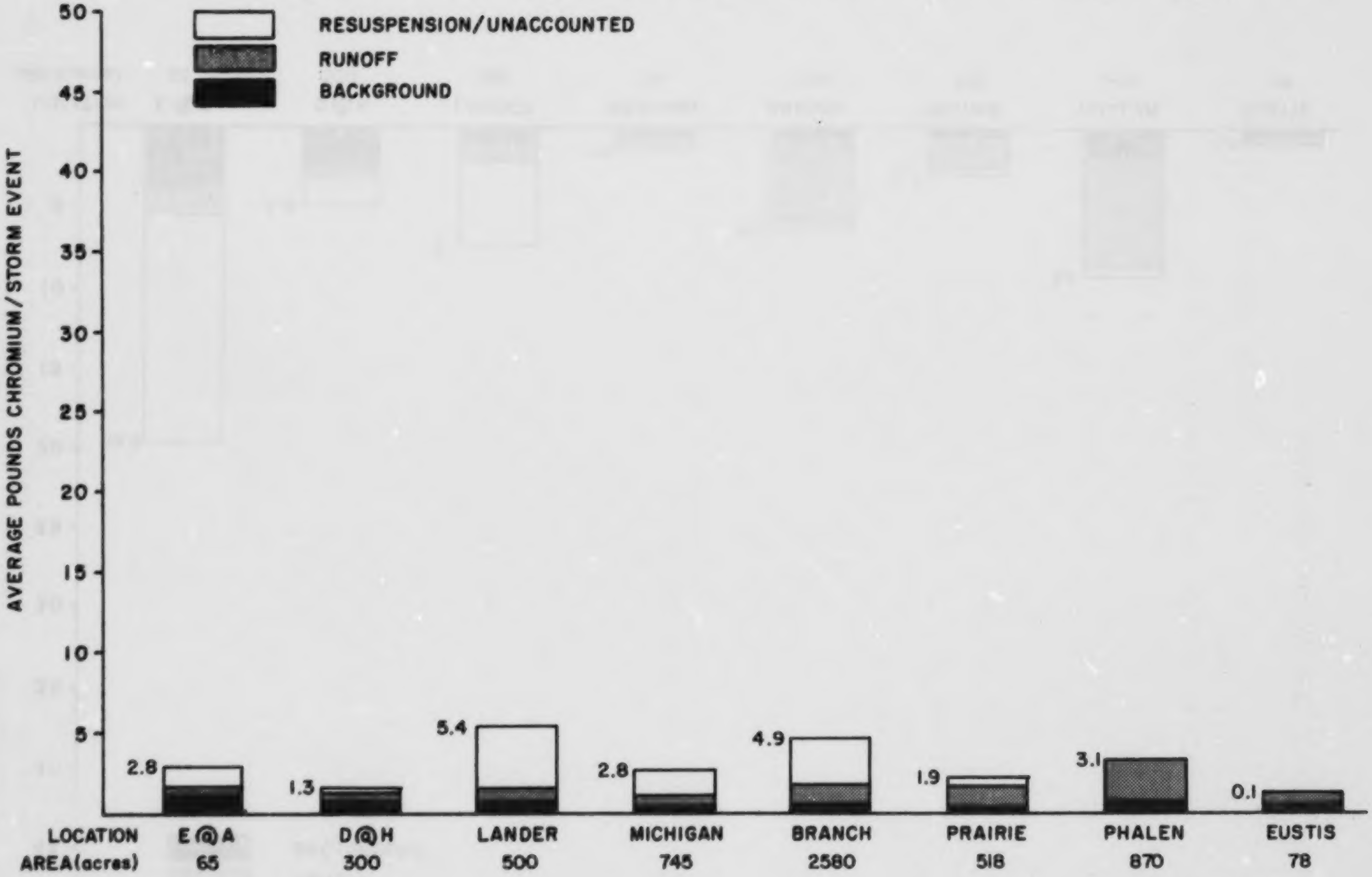


FIGURE 6.14 SOURCE OF CHROMIUM IN COMBINED SEWER FLOW

TABLE 6.8 SOURCES OF ZINC IN COMBINED SEWER FLOW

Location	Total CSF (lbs/storm event)	SOURCES (lbs/storm event) Background	Runoff	Resuspension/ Unaccounted
E @ A (3)	4.4	0.4	1.5	2.5
D @ H (3)	7.8	1.3	1.7	4.8
LANDER (3)	24.0	3.0	9.2	11.8
MICHIGAN (3)	4.6	1.3	3.0	0.3
PRAIRIE (3)	14.5	0.5	12.0	2.0
BRANCH (2)	48.5	3.5	28.4	16.6
EUSTIS (2)	0.6	0.03	0.4	0.2
PHALEN (2)	18.4	8.5	16.3	-[1]

[1] Sum of the background and runoff mass is in excess of the calculated CSF mass.
( )Number in parenthesis is the number of storm events.

TABLE 6.9 SOURCES OF LEAD IN COMBINED SEWER FLOW

Location	Total CSF (lbs/storm event)	SOURCES (lbs/storm event) Background	Runoff	Resuspension/ Unaccounted
E @ A (3)	1.3	0.1	1.2	0.0
D @ H (3)	2.4	0.3	2.2	0.0
LANDER (3)	8.7	1.7	9.1	-[1]
MICHIGAN (3)	4.2	0.7	2.8	0.7
PRAIRIE (3)	13.6	0.3	10.5	2.8
BRANCH (2)	39.1	0.3	37.6	1.2
EUSTIS (2)	1.4	0.05	0.8	0.6
PHALEN (2)	21.8	4.4	18.3	-[1]

[1] Sum of the background and runoff mass is in excess of the calculated CSF mass.
( )Number in parenthesis is the number of storm events.

TABLE 6.10 SOURCES OF COPPER IN COMBINED SEWER FLOW

Location	Total CSF (lbs/storm event)	SOURCES (lbs/storm event) Background	Runoff	Resuspension/ Unaccounted
E @ A (3)	5.1	1.6	1.1	2.4
D @ H (3)	6.1	1.7	0.3	4.1
LANDER (3)	18.8	4.2	2.1	12.5
MICHIGAN (3)	1.0	0.3	1.1	-[1]
PRAIRIE (3)	4.3	0.4	2.3	1.6
BRANCH (2)	11.4	0.1	4.1	7.2
EUSTIS (2)	0.2	0.02	0.1	0.08
PHALEN (2)	6.3	1.0	5.0	0.3

[1] Sum of the background and runoff mass is in excess of the calculated CSF mass.
( )Number in parenthesis is the number of storm events.

TABLE 6.11 SOURCES OF NICKEL IN COMBINED SEWER FLOW

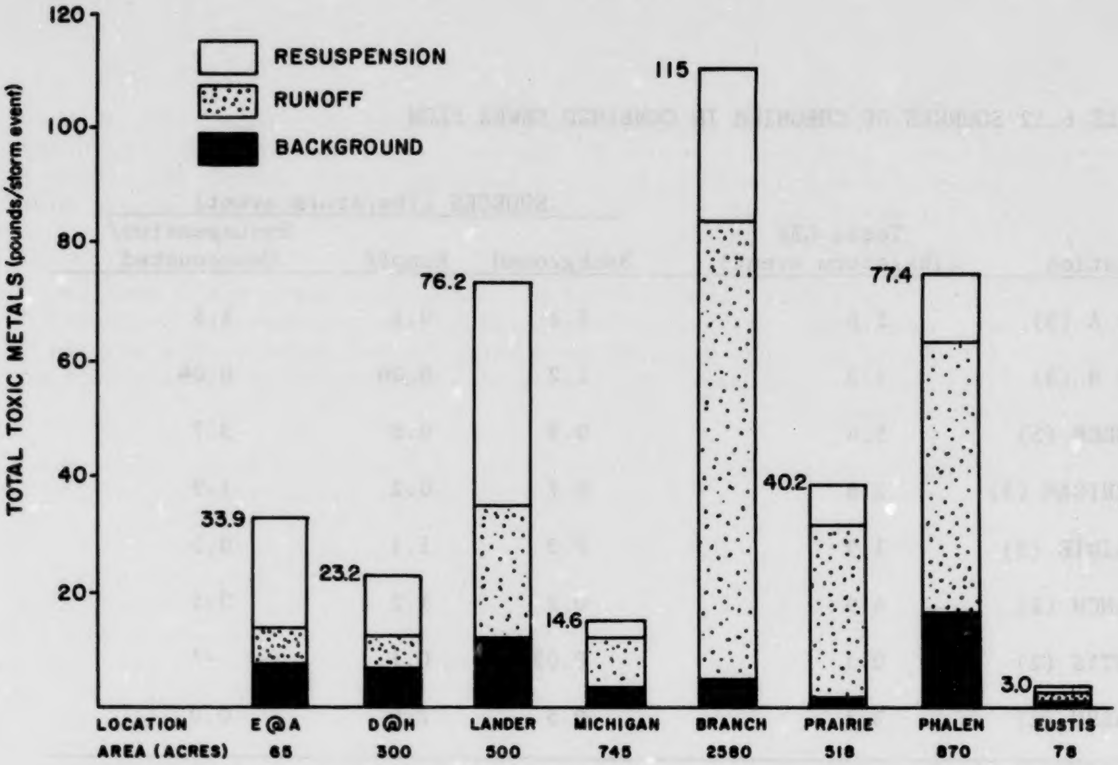
Location	Total CSF (lbs/storm event)	SOURCES (lbs/storm event) Background	Runoff	Resuspension/ Unaccounted
E @ A (3)	19.8	3.7	1.9	14.2
D @ H (3)	4.8	2.4	0.4	2.0
LANDER (3)	7.1	0.6	1.2	5.3
MICHIGAN (3)	1.0	0.4	0.5	0.1
PRAIRIE (3)	2.7	0.2	2.2	0.3
BRANCH (2)	6.1	0.3	5.6	0.2
EUSTIS (2)	0.3	0.01	0.3	0.0
PHALEN (2)	9.1	1.4	7.3	0.4

( )Number in parenthesis is the number of storm events.

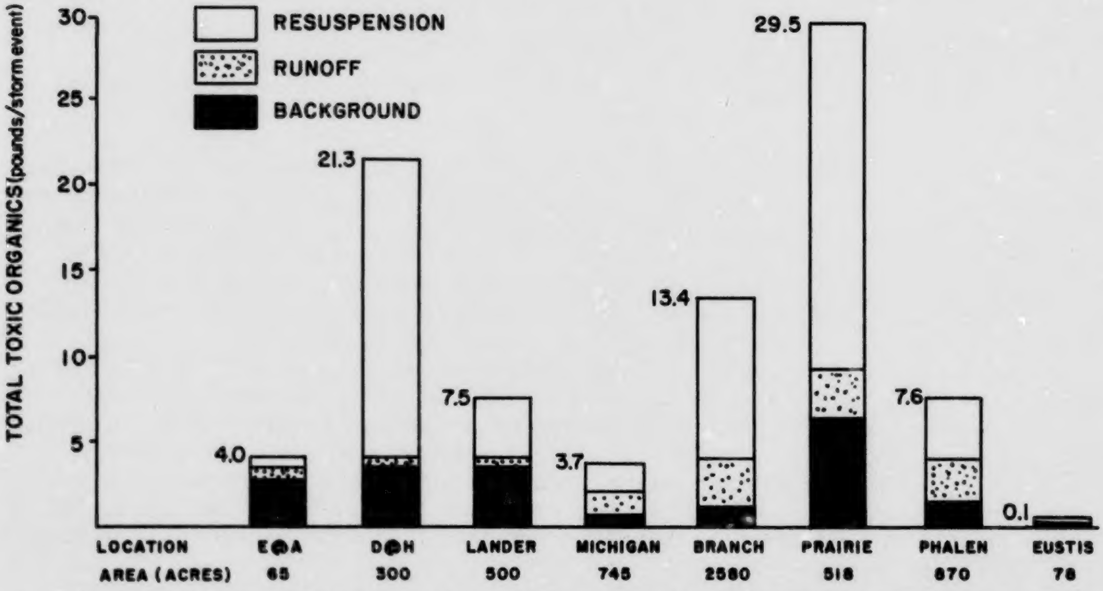
TABLE 6.12 SOURCES OF CHROMIUM IN COMBINED SEWER FLOW

Location	Total CSF (lbs/storm event)	SOURCES (lbs/storm event) Background	Runoff	Resuspension/ Unaccounted
E @ A (3)	2.8	1.2	0.1	1.5
D @ H (3)	1.3	1.2	0.06	0.04
LANDER (3)	5.4	0.9	0.8	3.7
MICHIGAN (3)	2.8	0.7	0.2	1.9
PRAIRIE (3)	1.9	0.3	1.1	0.5
BRANCH (2)	4.9	0.2	1.2	3.5
EUSTIS (2)	0.1	0.05	0.1	-[1]
PHALEN (2)	3.1	0.5	2.6	0.0

[1] Sum of the background and runoff mass is in excess of the calculated CFS mass.
( )Number in parenthesis is the number of storm events.



SOURCE OF TOTAL TOXIC METALS IN COMBINED SEWER FLOW



SOURCE OF TOTAL TOXIC ORGANICS IN COMBINED SEWER FLOW

FIGURE 6.15 SOURCE OF PRIORITY POLLUTANTS IN COMBINED SEWER FLOWS

per storm event at the Branch regulator to three pounds per storm event at the Eustis regulator. As stated previously, the nature of the industries tributary to the Ernest @ Allens (65 acres), Dexter @ Huntington (300 acres) and Lander (500 acres) drainage areas may account for the high CSF total toxic metals mass for these relatively small drainage areas.

In general, the greater the ratio of the background toxic metal mass to the CSF toxic metal mass, the greater the contribution attributable to resuspension. The Phalen drainage area, which during the two storm events sampled had no apparent toxic metal mass originating as resuspension, was the exception to the above observation.

Average total toxic organic pollutant mass in CSF ranged from 29.5 pounds per storm event at the Prairie regulator to 0.1 pounds per storm event at the Eustis regulator. Total toxic organic pollutant masses generated during the 22 storm events were much less than the total toxic metals mass (only about 20 percent of the total toxic metals). Toxic organic pollutant masses were the greatest in the Prairie and Dexter @ Huntington drainage areas. At the Prairie regulator, toluene and phenol pollutant masses accounted for the majority of the toxic organic pollutant mass. Trichloroethene and tetrachloroethene were the dominant toxic organic pollutants discharged at the Dexter @ Huntington location. With the exception of phenol (Prairie regulator only) and bis(2-ethylhexyl)phthalate, over 95 percent of the total toxic organic pollutant mass was from the volatile organic pollutant fraction.

The source of the toxic organics is attributed mostly to resuspension of settled material in the sewer systems. Background toxic organic masses at the Ernest @ Allens and Lander locations were surprisingly high (70 percent and 45 percent of the total toxic organic CSF mass, respectively), however, background toxic organic pollutant masses were less than 23 percent of the total CSF pollutant mass for the remaining six drainage areas. Runoff was not a major source of toxic organic pollutants.

Toxic pollutant masses for the 22 storm events were added to obtain total toxic pollutant masses for the most frequently detected priority pollutants and for several conventional/nonconventional pollutants. The results, which are presented in Table 6.13, show that with the exception of methylene chloride, the background pollutant mass does not represent a major portion of the CSF mass. The toxic pollutants associated with runoff were zinc, lead, and bis(2-ethylhexyl)phthalate. Runoff also had a large TSS contribution. The most startling observation, however, is the tremendous mass apparently associated with the resuspension of sediments in the combined sewer system. The percentages of the CSF mass attributed to resuspension of the metals copper, nickel, chromium, zinc, and lead were 59, 52, 51, 42, and 30 percent, respectively. Toluene, 1,1,1-trichloroethane, trichloroethene and tetrachloroethene masses from the resuspension of sediments each exceeded 78 percent of the total CSF mass. BOD_5 and COD masses attributed to resuspension also exceeded 50 percent of the total CSF mass.

Fate of Pollutants in Combined Sewer Systems--

Pollutants in combined sewer flows can either flow to a POTW for treatment

TABLE 6.13 SOURCES OF SELECTED POLLUTANTS IN COMBINED SEWER FLOWS[1]

Pollutant	Total Combined Sewer Flow (lbs)	SOURCES		
		Background (lbs)	Runoff (lbs)	Resuspension & Other Unaccounted Sources
Priority Pollutants				
Zinc	301	43	172	86
Copper	142	27	39	76
Chromium	59	14	15	30
Lead	215	18	191	6
Nickel	137	26	45	66
Total Toxic Metals	955	140	490	325
Methylene Chloride[2]	41	30	11	--
Toluene	30	4.8	0.9	24.3
1,1,1-Trichloroethane	30	1.5	--	28.5
Trichloroethene	64	14	0.4	49.6
Tetrachloroethene	20	2.1	0.4	17.5
Phenol	28	9.5	0.5	18
Bis(2-ethylhexyl)phthalate[2]	8.1	1.2	6.9	--
Naphthalene	1.0	0.1	--	0.9
Di-n-butyl phthalate[2]	1.4	0.1	1.4	--
Fluoranthene[2]	0.2	--	0.5	--
Total Toxic Organics	224	63	22	139
Conventional/Nonconventional Pollutants				
BOD_5	47,200	10,000	12,300	24,900
COD	249,800	46,900	49,600	153,300
TSS	229,400	19,100	109,000	101,300

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[1] Based on analytical results for samples collected during 21 storm events.

[2] Sum of the background and runoff mass are equal to or in excess of the CSF mass.

or be discharged to a receiving stream in the combined sewer overflow. Figure 6.16 illustrates the fate of pollutants in CSFs. Throughout this study the CSFs and CSOs were rigorously monitored and sampled. The difference in CSF and CSO mass was assumed to equal the mass discharged to the POTW.

Previous sections have shown that the concentrations of pollutants in CSF and CSO vary by drainage areas. Similarly, the fate of pollutants in combined sewer systems varies from drainage area to drainage area. The principle factor that affects the volume of CSF that can discharge to the POTW is the hydraulic capacity of the collection system (i.e., the regulator structures, spur pipes, and interceptor sewers). Figure 6.17 presents both the source and fate of the average CSFs by drainage area. Average CSF volumes ranged from 17.1 million gallons per storm event in the Branch drainage area to 0.5 million gallons per storm event in the Eustis drainage area. A comparison of the eight regulator structures, spur pipes and interceptors shows that the hydraulic capacity of the eight regulators, associated spur pipes, and interceptors fluctuates dramatically.

The operation of the regulator chambers sampled can be divided into two broad categories. The first case is the situation where during a portion of a storm event, the regulator/spur pipe/interceptor system is designed to route the entire CSF directly to the receiving waters as overflow. The Ernest @ Allens regulator is situated such that the interceptor system will surcharge during portions of storm events, thus preventing any CSF from the drainage area to reach the POTW during these surcharge periods. A sluice gate on the gatewell chamber at the Branch location was closed during a 45 minute period of one storm event thus preventing any CSF from discharging to the interceptor leading to the POTW during that time. The CATAD system in Seattle is designed to minimize the volume and number of CSO occurrences and maximize the in-line storage by opening and closing strategically located sluice gates within the combined sewer network. For this study the CATAD system was programmed to close the sluice gates at the entrance to the spur lines at the Michigan and Lander regulators. These elevations were selected to simulate CSO occurrences resulting from surcharged intereptor lines. During each of these interceptor surcharge conditions, CSF is discharged directly to the receiving streams as CSO until the water level in the interceptor allows a portion or all of the CSF from the drainage area to discharge to the POTW.

In contrast to the above interceptor surcharge condition is the more common situation where the spur pipe or regulator chamber structure limits the quantity of CSF that can be discharged to the interceptor. In this situation, a portion of the CSF continually discharges to the interceptor, the quantity in excess of the spur pipe and regulator structure hydraulic capacity is discharged as CSO. This condition existed at the Dexter @ Huntington, Prairie, Branch (on two occassions), Eustis and Phalen regulators. Figure 6.17 and the hydrographs in Appendix B show the flow patterns and fate of the CSF. For the 22 storm events sampled, the average CSO volume was 57 percent of the CSF volume.

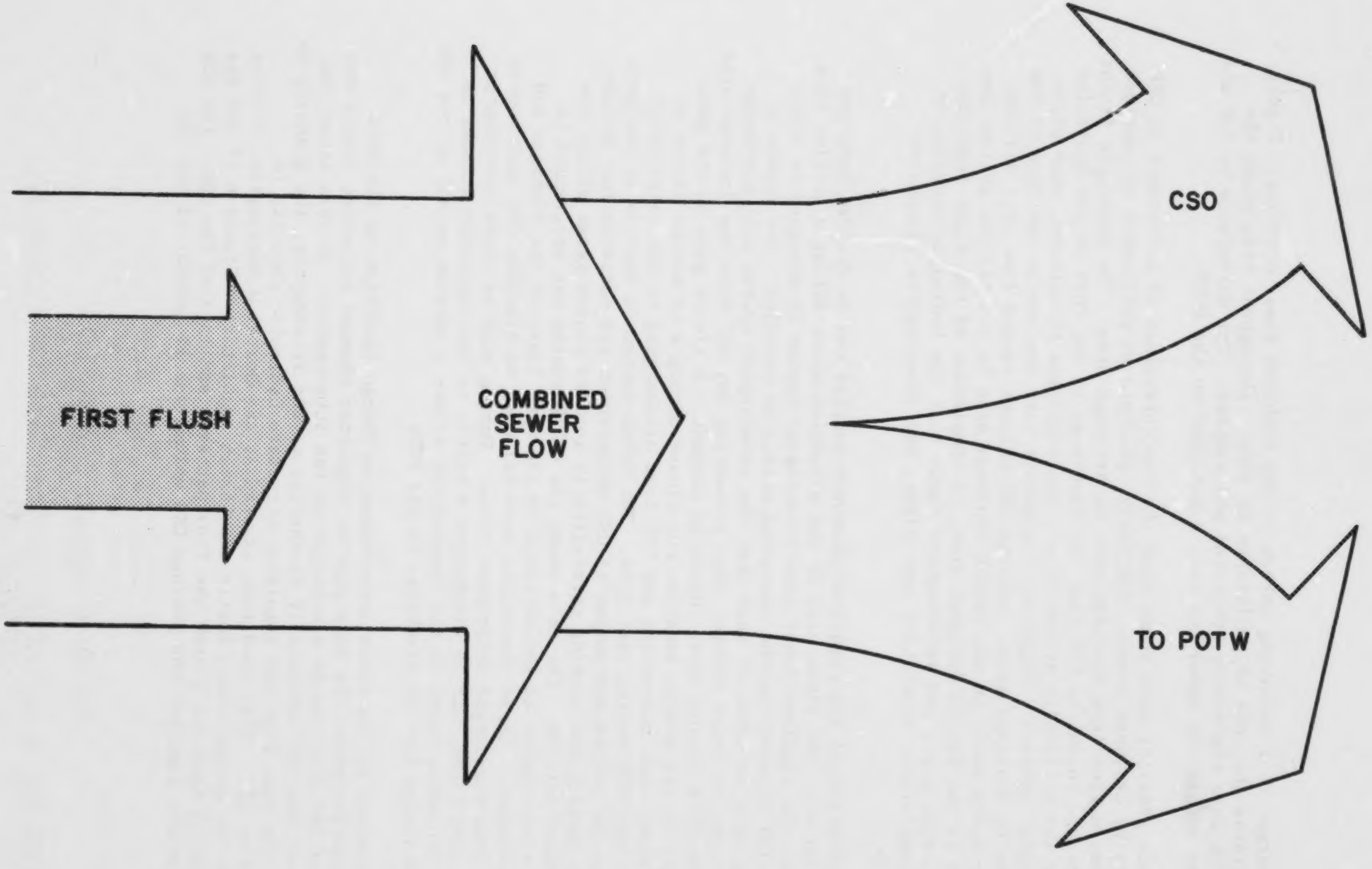
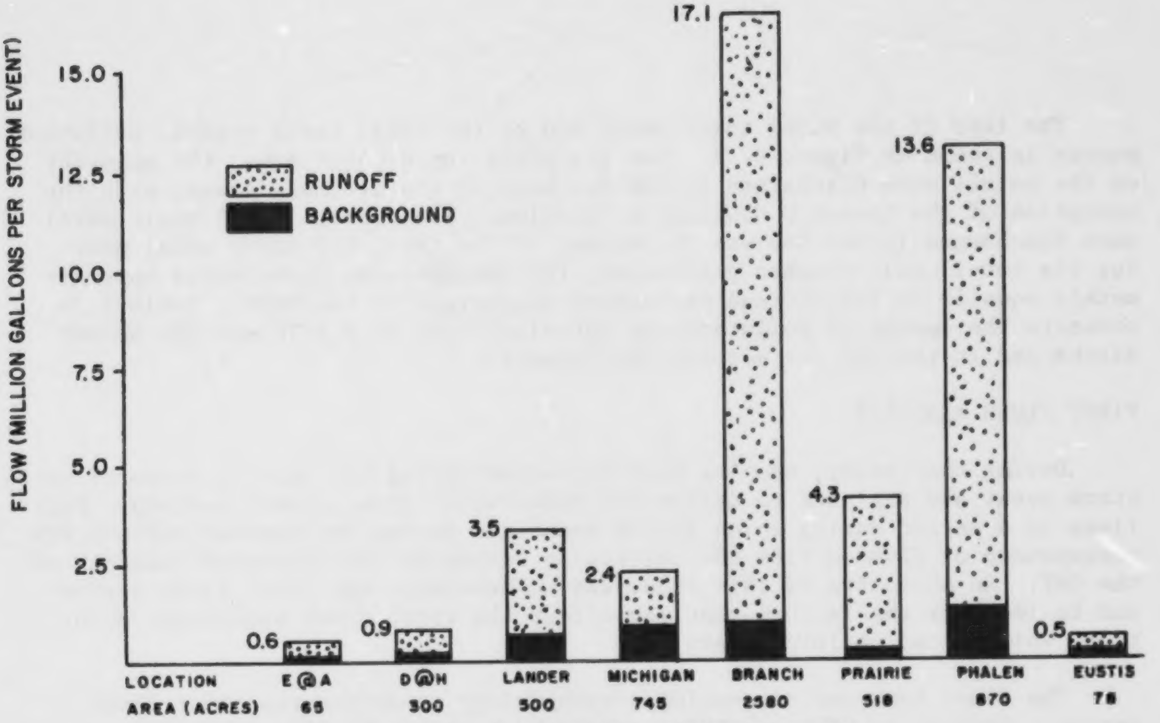
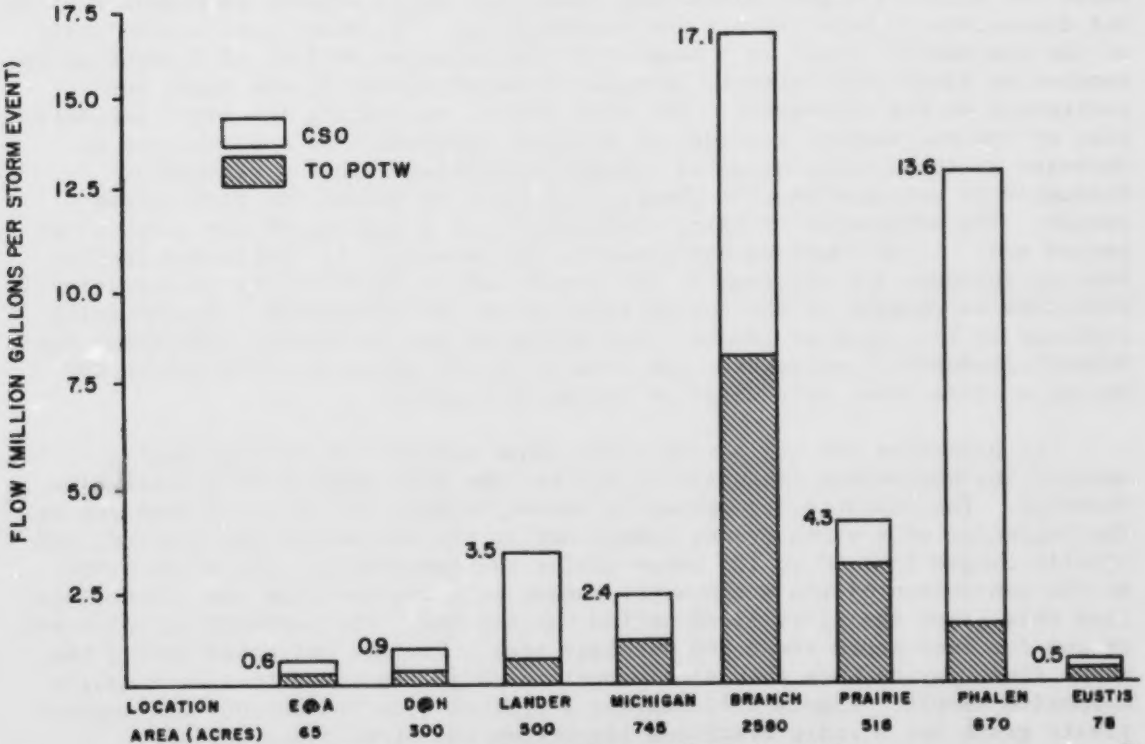

FIRST FLUSH
COMBINED SEWER FLOW
CSO
TO POTW

FIGURE 6.16 FATE OF POLLUTANTS IN COMBINED SEWER FLOWS



SOURCE OF COMBINED SEWER FLOW



FATE OF COMBINED SEWER FLOW

FIGURE 6.17 SOURCE AND FATE OF COMBINED SEWER FLOW

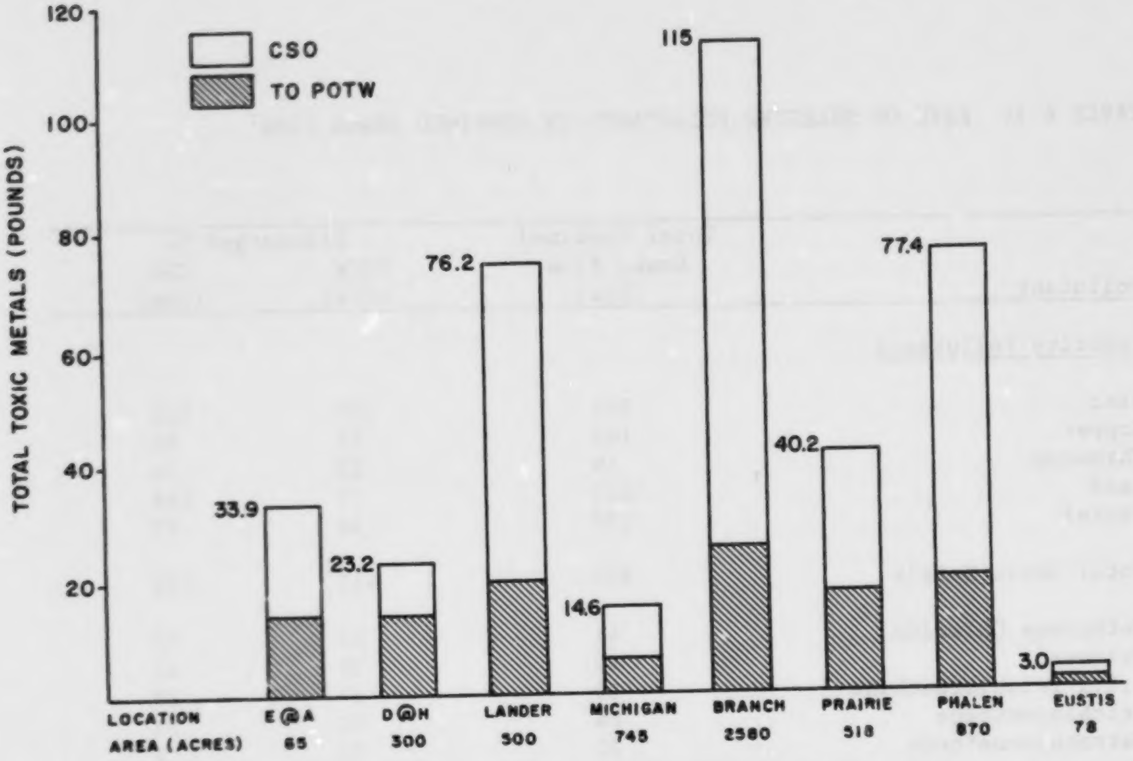
The fate of the total toxic metal and of the total toxic organic pollutant masses is shown in Figure 6.18. For the total toxic metal mass, the majority of the metals were discharged in CSO for each of the drainage areas, with the exception of the Dexter @ Huntington location. The average total toxic metal mass discharged in the CSO was 56 percent of the total CSF toxic metal mass. For the total toxic organic pollutants, the CSF mass was distributed approximately equally in the CSO and wastewater discharged to the POTW. Table 6.14 presents the amount of pollutants in CSF discharged to a POTW and the amount discharged in the CSO for selected pollutants.

FIRST FLUSH ANALYSIS

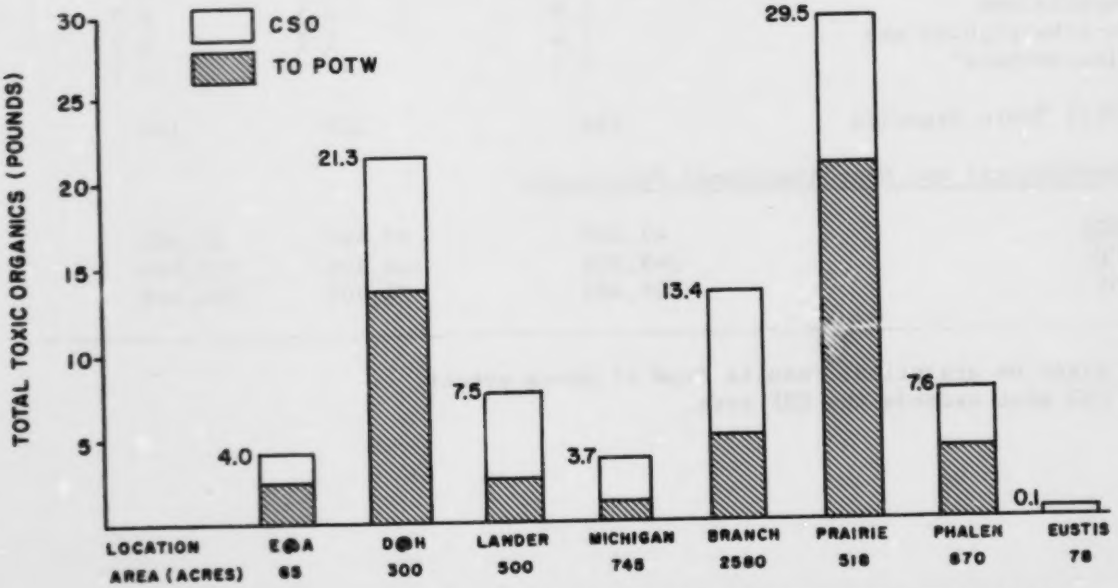
During this study, samples were collected during the initial phase of each storm event and analyzed to define any observable "first flush" periods. First flush is a period during which solids deposited during dry weather periods are resuspended or flushed from the collection system by the increased velocity of the CSF. An objective of this study was to determine the first flush period and to identify the factors that may affect the first flush magnitude, duration, volume, and pollutant mass.

The first task was to develop a methodology to define the first flush period. Generally, CSFs and CSOs contain high metal concentrations and are low in fats and other insoluble organic material. Most metallic salts, acids, and bases are relatively good electrical conductors while organic compounds that do not dissociate in water have a low conductivity. The electrical conductivity of the wastewater, which is a measure of the relative ability of a solution to conduct an electrical current, is directly proportional to the ionic concentration of the wastewater. For this reason, monitoring the ionic concentration of the wastewaters provides an accurate assessment of any increase or decrease in the concentration of inorganic pollutants in the wastewater. Conductivity was used in this study, therefore, to define the first flush period. The advantages of using conductivity as a measure of the first flush period are: 1) no sampling and analysis are required; 2) continuous instantaneous readouts are obtained in the field; and 3) conductivity is sufficiently sensitive to changes in the characteristics of the wastewater. Conductivity readings in the range of 300 to 2,000 micromhos per centimeter (µmhos/cm) for domestic/industrial wastewater and from 50 to 100 µmhos/cm for a dilute CSF during a storm event were measured during this study.

The procedure for collecting first flush samples was to continually monitor the wastewater conductivity and to take grab samples at a fixed time interval. The conductivity generally ranged between 300 to 2,000 µmhos/cm at the beginning of a storm event; diminished as the wastewater was diluted; and finally ranged from 50 to 100 µmhos/cm for the remainder of the storm event. At the conclusion of the storm event conductivity versus time was plotted and from this graph the first flush period was defined. The conductivity plot was unique for each storm event and drainage area. Samples collected during the first flush period were then flow proportionally composited to form a single composite sample. Figure 6.19 depicts a typical flow hydrograph, the conductivity graph for a storm event and identifies the first flush period.



FATE OF TOXIC METALS IN COMBINED SEWER FLOW



FATE OF TOTAL TOXIC ORGANICS IN COMBINED SEWER FLOW

FIGURE 6.18 FATE OF PRIORITY POLLUTANTS IN COMBINED SEWER FLOW

TABLE 6.14 FATE OF SELECTED POLLUTANTS IN COMBINED SEWER FLOW[1]

Pollutant	Total Combined Sewer Flow (lbs)	Discharged To POTW (lbs)	Discharged To CSO (lbs)
Priority Pollutants			
Zinc	301	109	192
Copper	142	56	86
Chromium	59	23	36
Lead	215	71	144
Nickel	137	48	89
Total Toxic Metals	955	417	538
Methylene Chloride	41	15	26
Toluene	30	19	11
1,1,1-Trichloroethane	30	17	13
Trichloroethene	64	31	33
Tetrachloroethene	20	11	9
Phenol	28	23	5
Bis(2-ethylhexyl)phthalate	8.1	1.2	6.9
Naphthalene	1.0	0.7	0.3
Di-n-butylphthalate	1.4	1.2	0.2
Flouranthene[2]	0.2	--	0.7
Total Toxic Organics	224	120	104
Conventional and Nonconventional Pollutants			
BOD5	47,200	25,800	21,400
COD	249,800	146,300	103,500
TSS	229,400	34,900	194,500

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[1] Based on analytical results from 21 storm events.

[2] CSO mass exceeds the CSF mass.

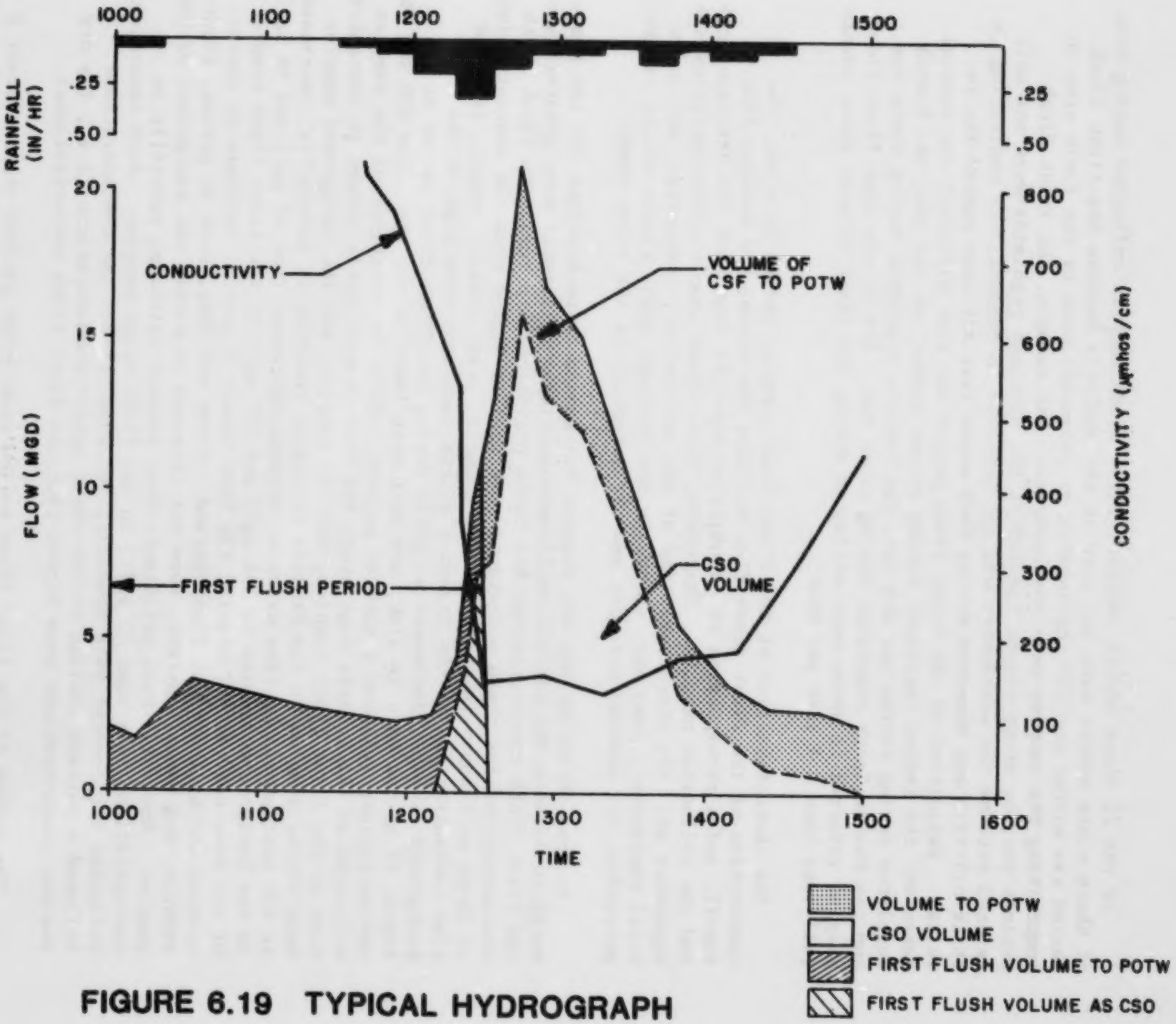

FIGURE 6.19 TYPICAL HYDROGRAPH

Of the 22 storm events sampled, first flush samples collected during nine of these storm events were not used in the analysis because the first flush period was either not distinguishable or judgments made by the field crew in compositing the samples were not accurate. For example, the first flush periods for the storm events sampled at the Michigan regulator were not well defined because the wastewater was not amenable to conductivity monitoring (a thick oil-film was observed during each storm that may have masked the results). Definition of the first flush period was also difficult for samples taken at: the Lander regulator during storms number one and two; the Branch regulator during storms one and two; the Prairie regulator during storm one; and the Phalen Creek regulator during storm two. Six of the nine first flush samples referred to above were collected during the least intense storm events (all less than 0.1 inch per hour).

The characteristics of the first flush samples varied by site. The composition of the first flush flow includes the normal dry weather flow, runoff, and a resuspension of accumulated deposits from both the drainage area and the collection network. Therefore, first flush sample characteristics are dependent on: the characteristics of the residential, commercial, and industrial wastewater; land use; slopes in the drainage area; slopes of the sewers; antecedent dry weather periods; and the intensity of the storm event.

In most instances the dry weather background concentrations for the toxic metal pollutants and conventional/nonconventional pollutants were greater than the first flush concentrations for those pollutants; in turn, the first flush concentrations for those pollutants were usually higher than the concentration of those pollutants in the CSO. For example, lead, nickel, copper, iron and zinc concentrations at the Ernest @ Allens regulator were high in the background samples, decreased slightly during the first flush period as a result of an increase in flow, and were even lower in the CSO. The COD and TSS concentrations followed a similar pattern. With the exception of the samples collected at the Prairie regulator, the VOCs showed little change in concentration in the first flush samples, the CSO samples, and the background samples. Both storms sampled at the Prairie regulator resulted in substantial increases in VOC concentrations (for example, toluene increased from 42 µg/l and 86 µg/l in the background samples to 164 µg/l and 937 µg/l in the first flush samples). Of the base-neutral pollutants, the PAHs showed a general increase in concentration during the first flush period. Often the PAHs, such as pyrene, fluoranthene, and benzo(a)pyrene, were not detected in either the background or CSO samples. However, these pollutants were present (although generally in concentrations less than 10 µg/l) in the first flush samples. Acid extractable pollutant occurrences were sporadic, but when present the concentrations followed a pattern similar to the toxic metals concentrations (i.e., the dry weather concentrations were higher than the first flush concentrations).

The volume of the first flush varied from 1,500 gallons at the Ernest @ Allens location (two percent of the combined sewer flow for that storm event) to 4,610,000 gallons at the Branch location (21 percent of the combined sewer flow for the storm event). The average first flush volume for the 13 storm events was 825,000 gallons or 15 percent of the average combined sewer flow (5,508,000 million gallons per storm event). Figure 6.20 shows the CSF, CSO, and first flush volumes for the 13 storm events sampled. This figure also

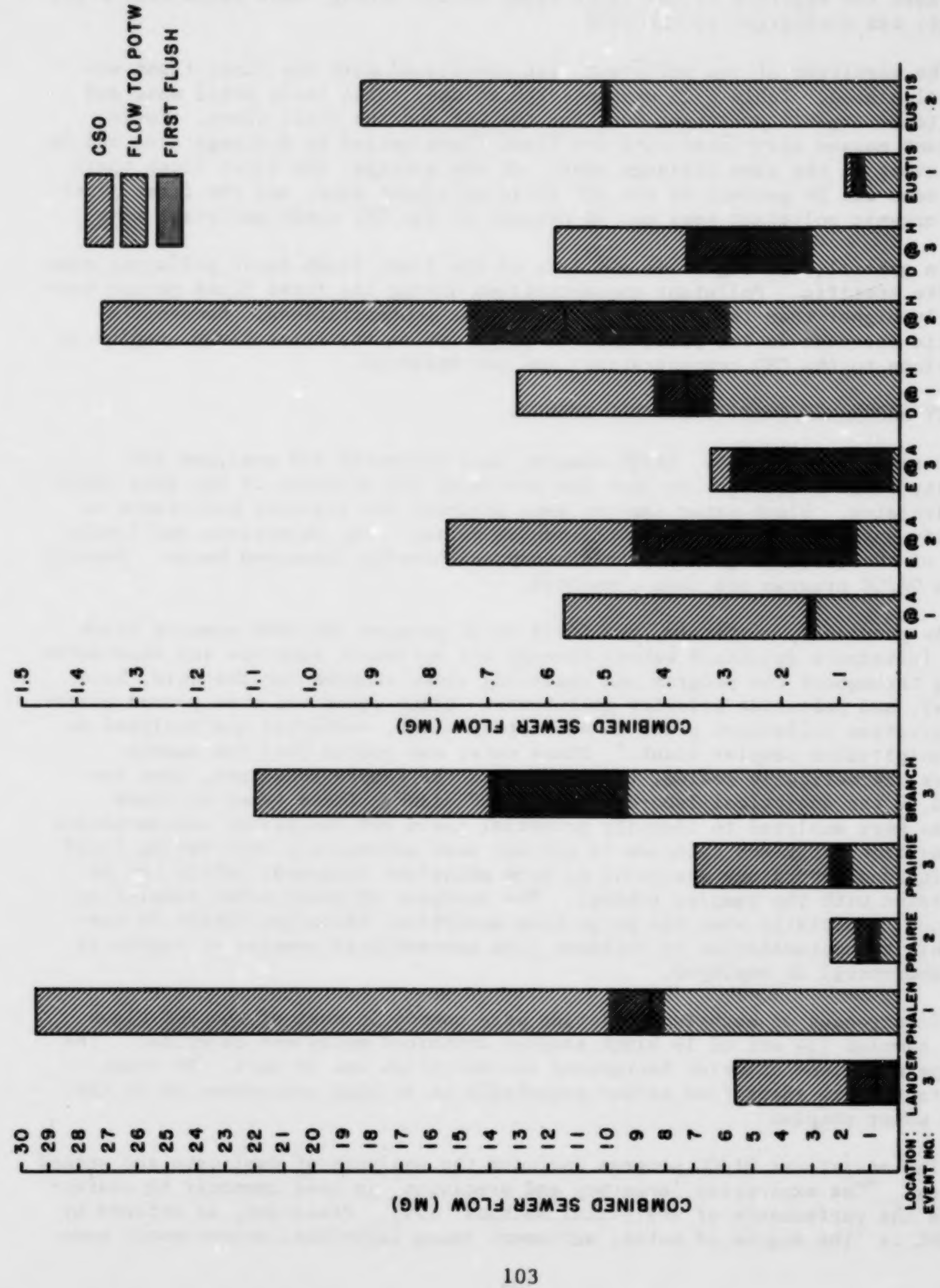

FIGURE 6.20 FIRST FLUSH VOLUMES PER STORM EVENT

shows that the majority of the first flush volume during these storm events (65 percent) was discharged to the POTW.

The magnitude of the pollutant mass associated with the first flush was also calculated. Table 6.15 presents the volume, total toxic metal mass and total toxic organic pollutant mass for the CSF and the first flush. Toxic pollutant masses associated with the first flush varied by drainage area and by storm event in the same drainage area. On the average, the first flush toxic metal mass was 24 percent of the CSF toxic pollutant mass; and the first flush toxic organic pollutant mass was 40 percent of the CSF toxic pollutant mass.

In general, the magnitude and fate of the first flush toxic pollutant mass was site specific. Pollutant concentrations during the first flush period were normally higher than the CSF and CSO pollutant concentrations. However, a dramatic increase in the pollutant concentration in the first flush samples in comparison to the CSO concentrations was not observed.

QUALITY ASSURANCE/QUALITY CONTROL RESULTS

During the CSO study, QA/QC samples were collected and analyzed for priority toxic pollutants so that the precision and accuracy of the data could be calculated. Blank water samples were analyzed for priority pollutants to identify any sampling or analytical contamination. The objectives and limitations of the QA/QC program for this study are briefly discussed below. Results of the QA/QC program are then presented.

As previously mentioned, the field QA/QC program included pumping blank water (ultrapure deionized water) through all automatic samplers and associated tubing throughout the program and analyzing these samples for the acid, base/neutral, and pesticide priority pollutants. Blank water was also poured across precipitation collectors prior to each storm event, collected and analyzed as a "precipitation sampler blank." Blank water was poured into VOC sample bottles, hermetically sealed, transported to the sample locations, then forwarded to the analytical laboratory as a VOC blank. These types of blank samples were analyzed to identify potential field and analytical contamination such as from methylene chloride (a solvent used extensively both during field sampling and laboratory analysis) or from phthalate compounds (which may be associated with the sampler tubing). The analysis of blank water samples is critical, especially when the purge-trap analytical technique (which is susceptible to contamination by residues from concentrated samples or vapors in the laboratory) is employed.

Occurrences of methylene chloride were common in most of the VOC blank water samples (14 out of 18 blank samples contained methylene chloride). The average methylene chloride background concentration was 16 μg/ℓ. No other pollutants were identified either repeatedly or in high concentration in the blank water samples.

The analytical QA/QC program included the analysis of duplicate and spiked samples. "The expression 'accuracy and precision' is used commonly to characterize the performance of analytical methods" (30). Precision, as defined by the EPA is "the degree of mutual agreement among individual measurements made

TABLE 6.15 FIRST FLUSH VOLUMES AND TOXIC POLLUTANT MASSES

	Volume (MG)			Total Toxic Metals (lbs)			Total Toxic Organic Pollutants (lbs)		
Drainage Area-Event No.	CSF	First Flush	Percent of CSF	CSF	First Flush	Percent of CSF	CSF	First Flush	Percent of CSF
Lander - 3	5.680	1.650	29	111.0	17.0	15	5.4	0.6	11
Phalen - 1	29.400	1.730	6	137.0	10.0	7	14.0	1.0	7
Prairie - 2	2.280	0.830	36	7.2	4.1	57	35.0	20.0	57
Prairie - 3	6.980	0.440	6	76.0	7.4	10	8.5	2.3	27
Branch - 3	22.000	4.600	21	240.0	50.0	21	18.0	3.7	21
E @ A - 1	0.570	0.002	1	17.0	0.05	1	0.4	<0.1	25
E @ A - 2	0.760	0.390	51	81.0	52.0	64	8.1	8.5	100
E @ A - 3	0.320	0.290	91	3.8	4.6	100	3.4	1.8	53
D @ H - 1	0.650	0.100	15	10.0	2.4	24	6.2	1.1	18
D @ H - 2	1.360	0.450	33	47.0	23.0	49	52.0	22.0	42
D @ H - 3	0.580	0.220	38	13.0	5.6	43	7.1	2.4	34
Eustis - 1	0.098	0.016	16	0.7	1.0	100	<0.1	0.1	100
Eustis - 2	0.920	0.006	1	5.4	0.1	2	0.2	<0.1	50
Average	5.508	0.825	15	57.6	13.6	24	12.2	4.9	40

under prescribed conditions with a single test procedure" (31). The precision of the analytical results refers to the ability to reproduce the same results, regardless of whether the results are true values or the result of systematic analytical errors. The smaller the difference in analytical results for duplicate wastewater or duplicate spiked samples the higher the analytical precision. During this program, both duplicate wastewater and duplicate spiked samples were analyzed. Precision results were calculated by determining the relative percent difference between the duplicate sample concentrations.

Accuracy (or validity) on the other hand, is defined by the EPA as "the difference between an average value and the true value when the latter is known or assumed" (31). Accuracy can be defined for a given sample matrix by measuring the percent recovery of known concentrations of priority pollutants or surrogate compounds that are spiked into both wastewater and blank water samples.

"Method spike" results reflect the recoveries of known concentrations of surrogate or priority pollutant "cocktails" that are spiked into blank water samples. Surrogate compounds, which are compounds that behave in the same manner as the priority pollutants they represent (but are unlikely to occur in the environment), were added to all organic pollutant samples analyzed using EPA Methods 1624 and 1625 and to a limited number of samples analyzed using EPA Methods 624 and 625. The analysis performed by isotope dilution (Methods 1624 and 1625) were adjusted based on the surrogate recoveries. Organic pollutant concentrations for samples collected from the Lander and Michigan drainage areas were not adjusted based on surrogate recoveries because Methods 624 and 625 were used to analyze those samples.

Known concentrations of the 13 toxic metals were added to the metals samples. The method spike results describe the accuracy of the analytical methods for deionized water samples. Matrix spike results reflect the recoveries of known concentrations of either surrogate compounds (organic fraction) or priority pollutants (metal fraction) spiked into the wastewater samples and describe the accuracy of the analytical methods for the wastewater samples. Appendix D contains the results of the QA/QC program.

The accuracy of the volatile organic pollutant data for both method spike samples (blank water) and matrix spike samples (wastewater samples) during this study was good with a mean recovery of 96 ± 12 percent and 96 ± 15 percent, respectively. The only VOCs found consistently above the analytical detection limits throughout this study were methylene chloride, toluene, and 1,1,1-trichloroethane. These compounds had matrix recoveries of 102 ± 22, 102 ± 11 and 94 ± 15 percent, respectively. These recoveries indicate that the concentrations found for these compounds are accurate (i.e., the difference between the observed surrogate compound concentration and the true surrogate concentration is small). As mentioned previously, the consistent presence of methylene chloride in the blank samples is indicative of field and/or laboratory contamination. In general, reported "ND" values should be considered valid since the wastewater spike sample recovery data demonstrate that the analytical method is suitable for the sample matrix. Appendix D-1 contains the volatile organic percent recovery results.

The precision (reproducability) of the spiked duplicate VOC analyses was much better than the precision of the unspiked duplicate VOC analyses, an enigma because all of the volatile compound surrogates were analogs of priority pollutants and should have behaved similar to priority pollutants. Appendix D-2 presents the relative percent differences for the unspiked volatile organic duplicate and spiked volatile organic duplicate compounds. The relative percent difference is calculated as the difference in duplicate analysis divided by the average concentrations of the duplicate analysis, multiplied by 100.

The mean percent recovery (accuracy) for the base-neutral pollutants (i.e., 81 ± 23 percent) is considered very good; throughout the CSO study, occurrences of base-neutral compounds were sporadic. Bis(2-ethylhexyl)phthalate was the only base-neutral pollutant detected above the analytical detection limit a majority of the time. The mean percent recovery for the bis(2-ethylhexyl)phthalate surrogate matrix spike sample was 84 ± 28 percent. The standard deviation signifies some scattering of the results. With the exception of dimethyl phthalate-3,4,5,6-d$\underline{4}$, 1,2-dichlorobenzene-3,4,5,6-d$\underline{4}$ and 1,4-dichlorobenzene-2,3,5,6-d$\underline{4}$ (percent recoveries of 27 ± 15, 59 ± 22, and 54 ± 19, respectively), all base-neutral recoveries were over 75 percent. Therefore, "ND" values can be considered reliable, again indicating that the analytical methods were accurate for the wastewater matrix. Appendix D-3 presents the base-neutral surrogate percent recoveries for this study.

Precision data for duplicate base-neutral samples are limited due to the sporadic occurrences of the base-neutral pollutants in the 21 duplicate samples analyzed. Bis(2-ethylhexyl)phthalate was the most frequently occurring base-neutral pollutant, present in six of the 21 duplicate wastewater samples. The 37.1 percent average difference for this pollutant between duplicate analyses compares favorably with the percent difference of the 16 spiked duplicate wastewater samples in which the bis(2-ethylhexyl)phthalate-3,4,5,6-d4 average percent difference was 33.1 percent. Appendix D-4 summarizes the base-neutral precision data.

The acid extractable pollutant fraction had the poorest accuracy of all sample fractions with an overall percent recovery of 61 ± 26 percent. Recoveries ranged from 82 ± 34 for pentachlorophenol-13-c$\underline{6}$ to 29 ± 34 for 4,6-dinitro-2-methyl phenol-3,5-d$\underline{2}$. Phenol was the most frequently detected acid extractable pollutant; it was detected less than 30 percent of the time. The average percent recovery for phenol was 45 ± 19. Appendix D-5 presents the surrogate matrix spike results for the acid extractable fraction.

As with the base-neutral pollutants, the acid extractable pollutant unspiked duplicate analyses results were comparable to the spiked duplicate analyses results. However, the unspiked wastewater duplicate analysis precision data are limited due to only sporadic occurrences of the acid extractable compounds in the wastewater samples analyzed. The acid extractable pollutant precision data are fair, although the accuracy of the acid extractable data are poor. Appendix D-6 presents the relative percent differences for the duplicate acid extractable analyses.

The average mean recovery for the 13 priority pollutant metals analyzed was 97 ± 8 percent. For the metals analyzed by atomic absorption spectrometry (selenium, thallium, silver, arsenic, antimony and mercury), the average percent recovery was 101 ± 13 percent. The poorest recovery of these elements was for thallium (76 ± 12 percent). The remaining priority pollutant metals were analyzed by plasma emission spectrometry. The average percent recovery for these seven elements (beryllium, cadmium, chromium, copper, lead, nickel, and zinc) was 94 ± 5 percent. Recoveries ranged from 89 ± 8 percent for copper to 99 ± 4 percent for chromium. Appendix D-7 presents the metals percent recoveries. Overall, the recoveries for the metals analyses were very good for this CSO study, indicating that the concentrations presented should be considered accurate.

With the exception of silver, the precision of the metals results was very good. The average relative percent difference for the duplicate analyses for the most frequently detected elements (i.e., zinc, copper, chromium, lead, and nickel) was 9.4, 8.9, 11.2, 6.0 and 3.4, respectively. Duplicate spiked analyses were not run for toxic elements. Appendix D-8 contains a summary of the average relative percent difference for the duplicate metal analyses.

APPENDIX A
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REFERENCES

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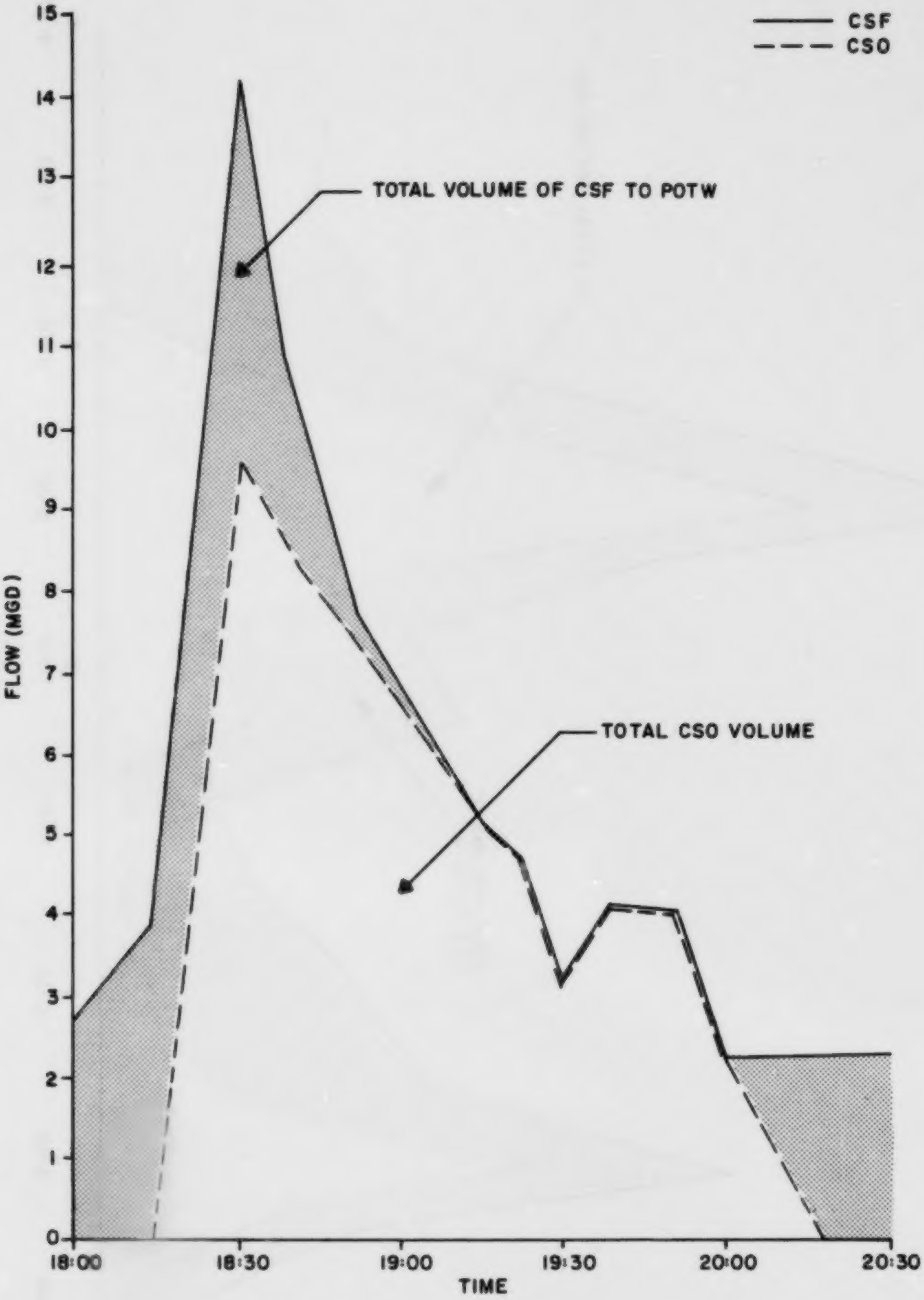
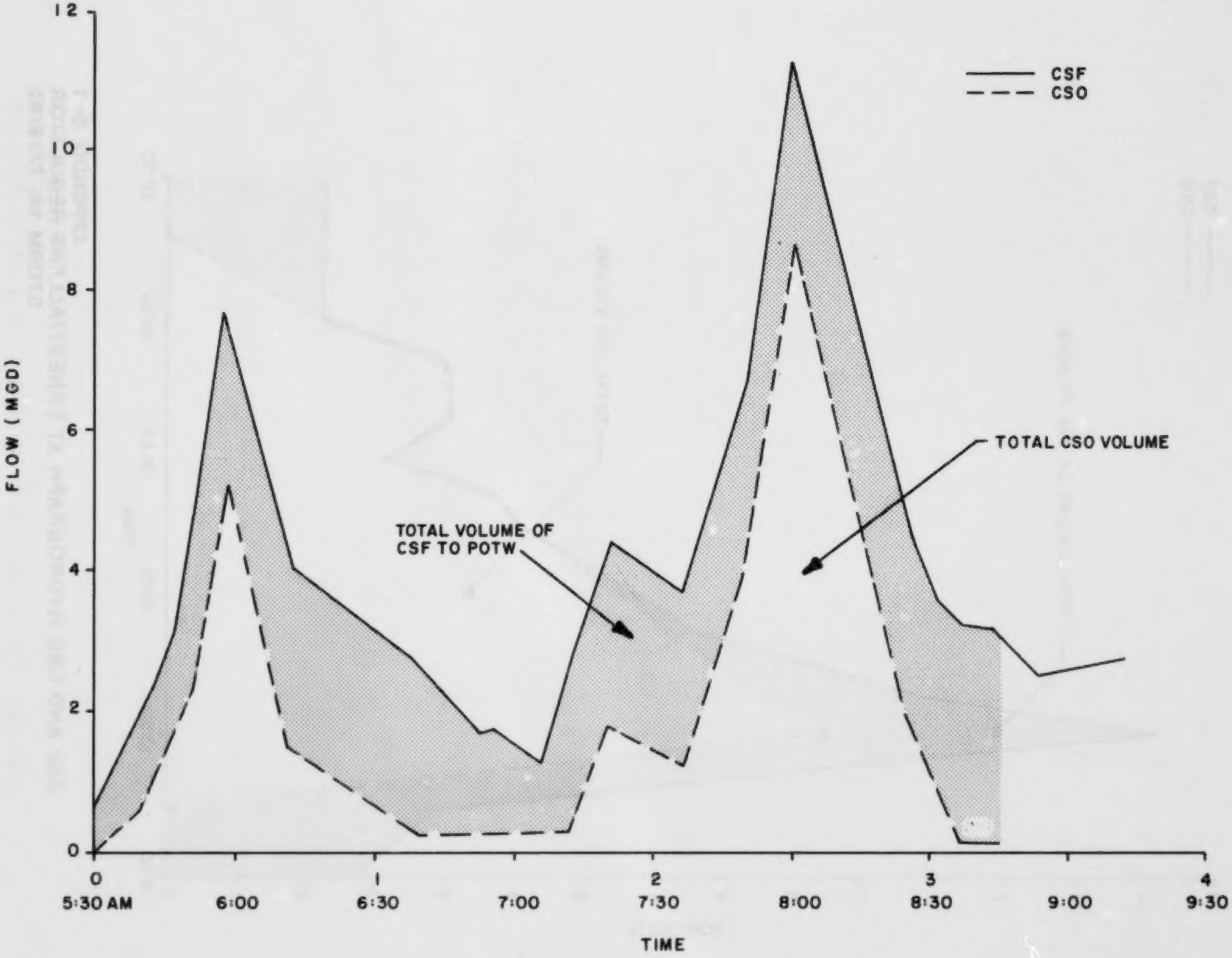
APPENDIX B
STORM HYDROGRAPHS

FIGURES

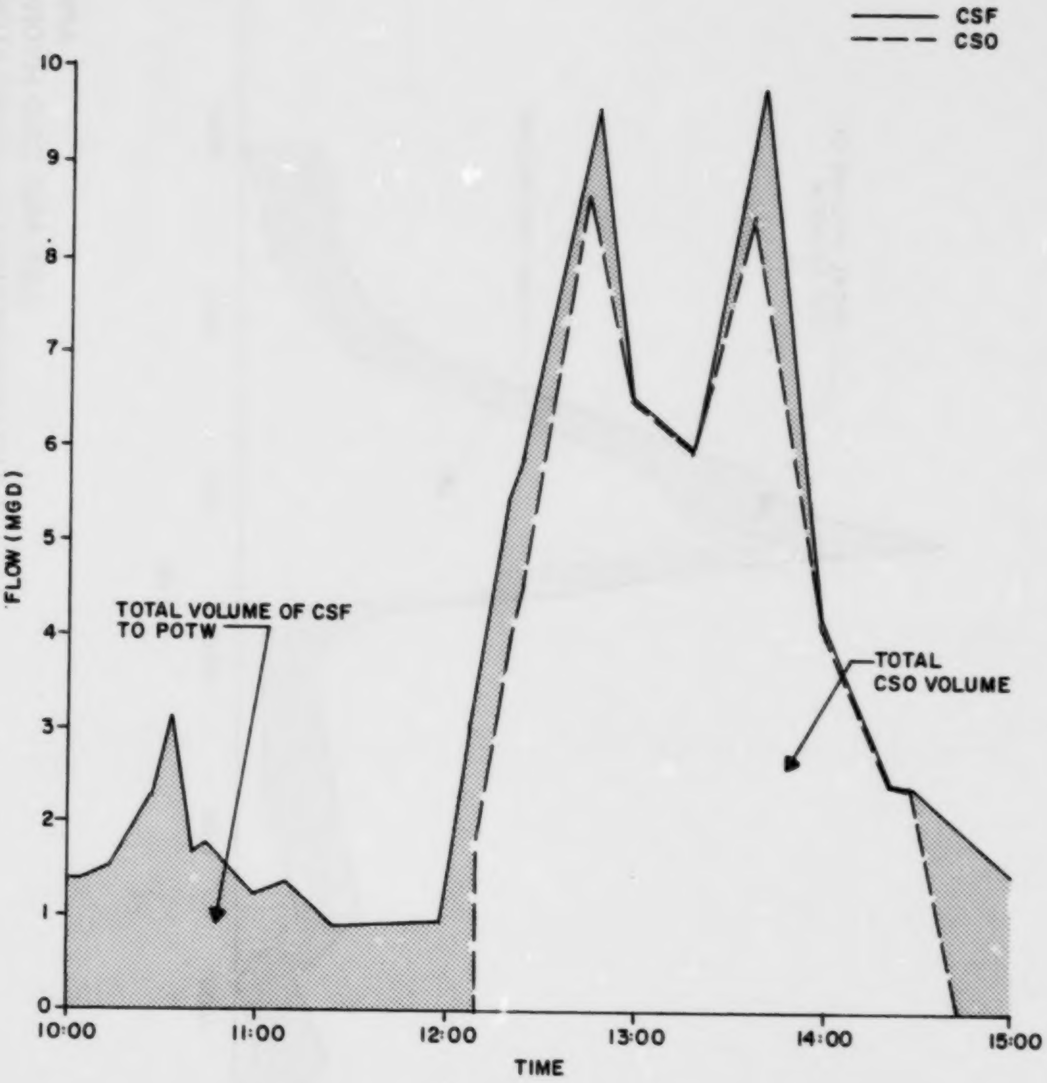
B-1 thru B-6	Providence, Rhode Island, Storm Events
B-7 thru B-12	Seattle, Washington, Storm Events
B-13 thru B-18	St. Louis, Missouri, Storm Events
B-19 thru B-22	St. Paul, Minnesota, Storm Events



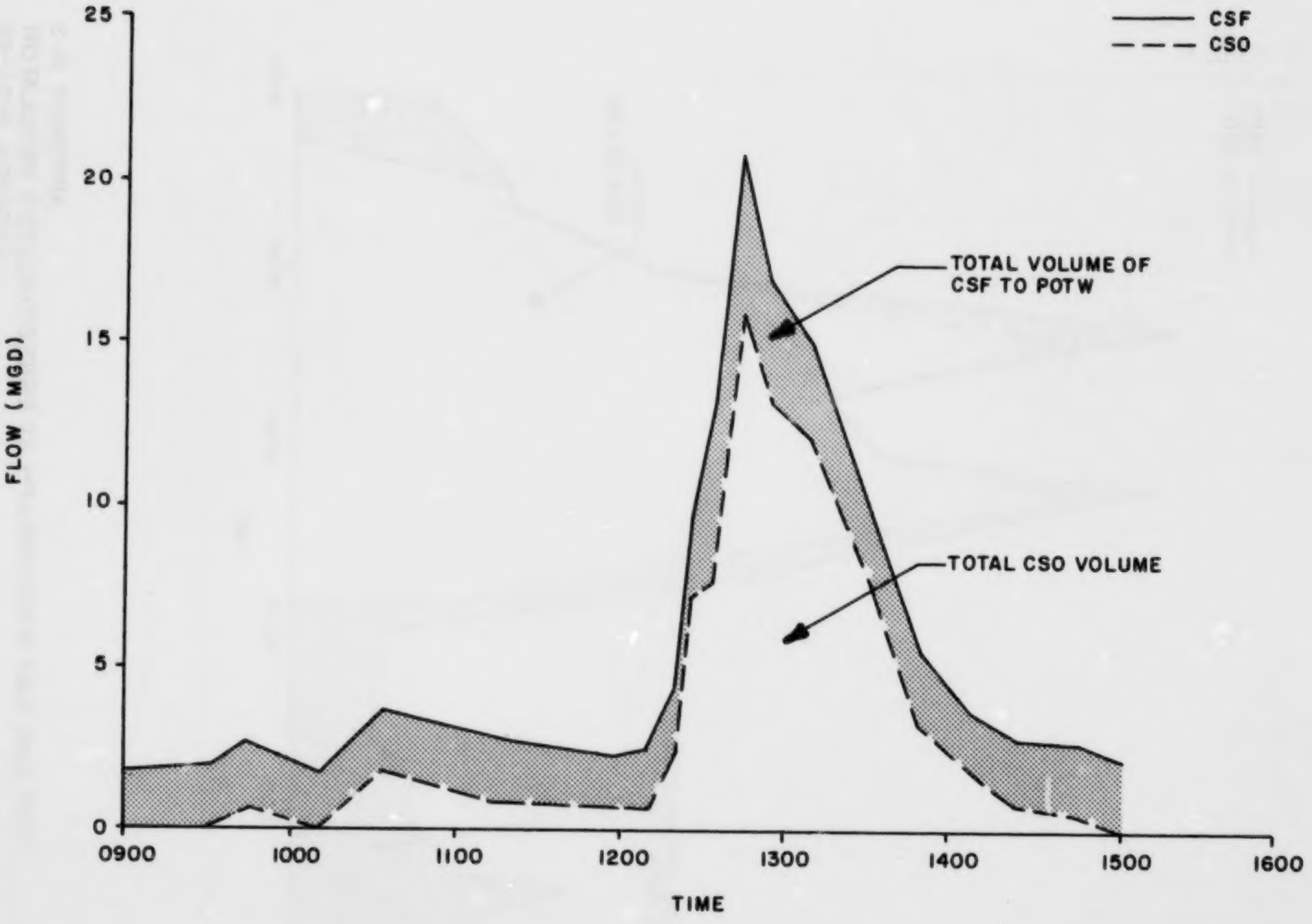
APPENDIX B-1
CSF AND CSO HYDROGRAPH AT ERNEST/ALLENS REGULATOR
STORM 1A, 7/19/82



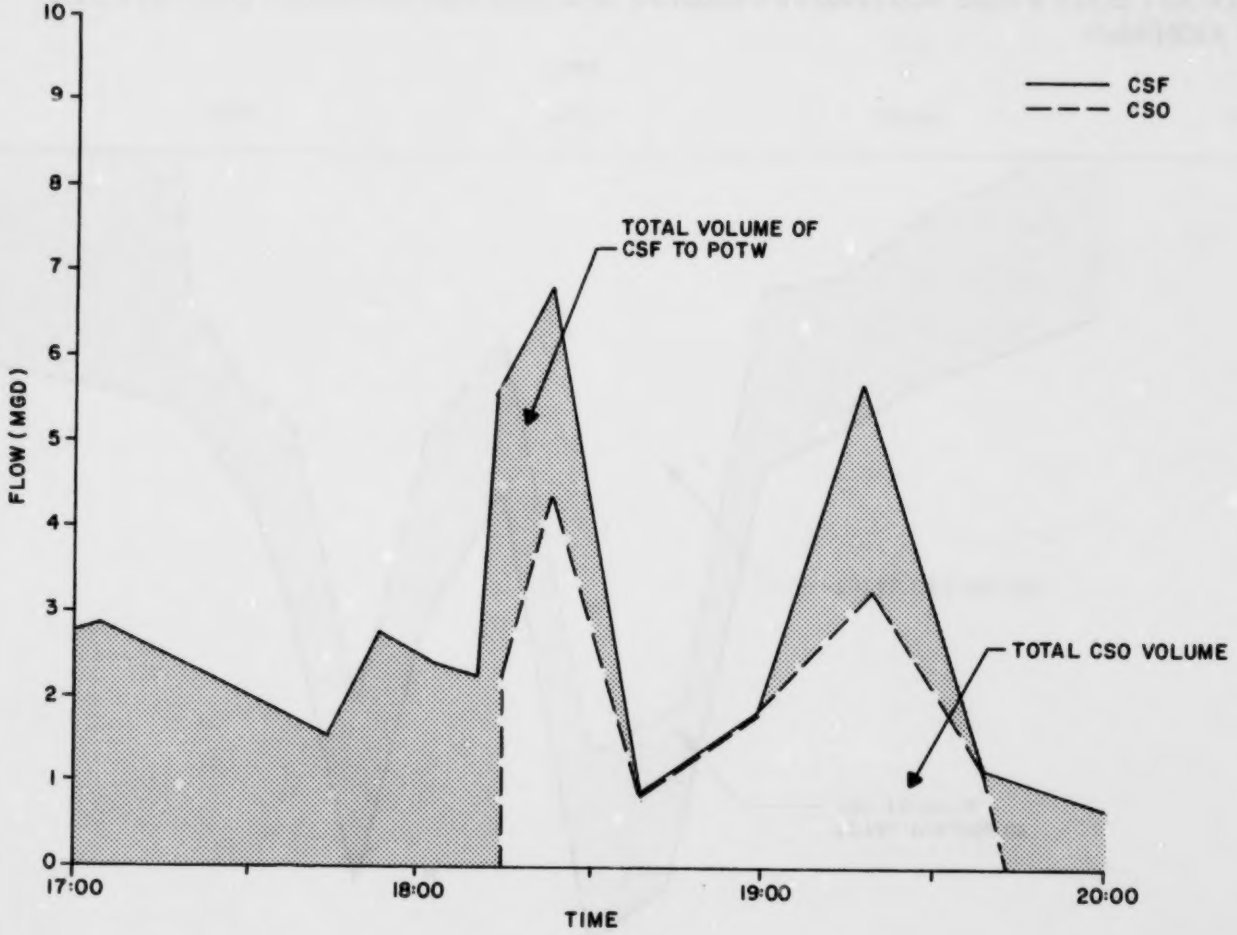
APPENDIX B-2
CSF AND CSO HYDROGRAPH AT DEXTER/HUNTINGTON REGULATOR
STORM 1B, 8/9/82



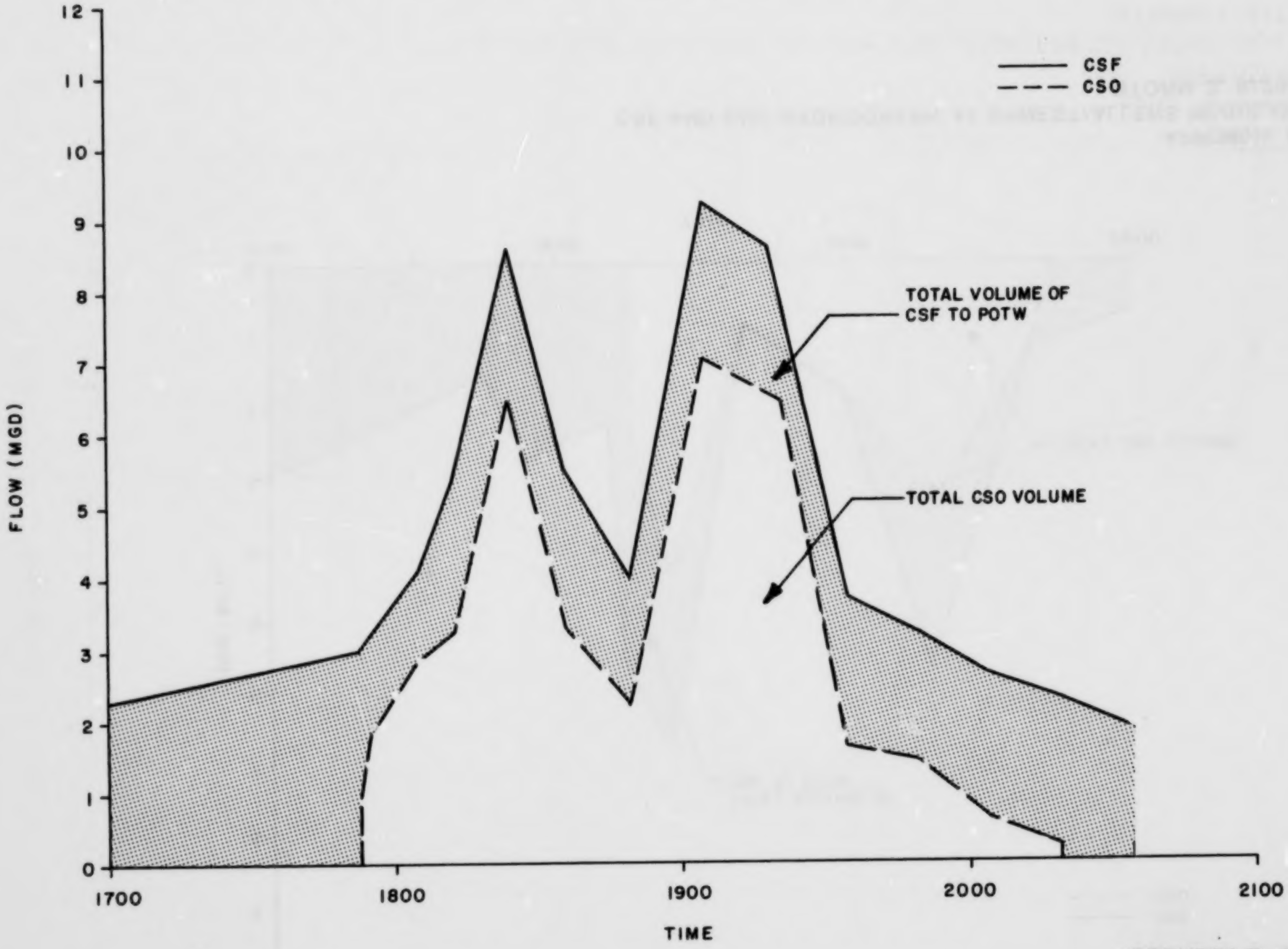
APPENDIX B-3
CSF AND CSO HYDROGRAPH AT ERNEST/ALLENS REGULATOR
STORM 2, 8/25/82



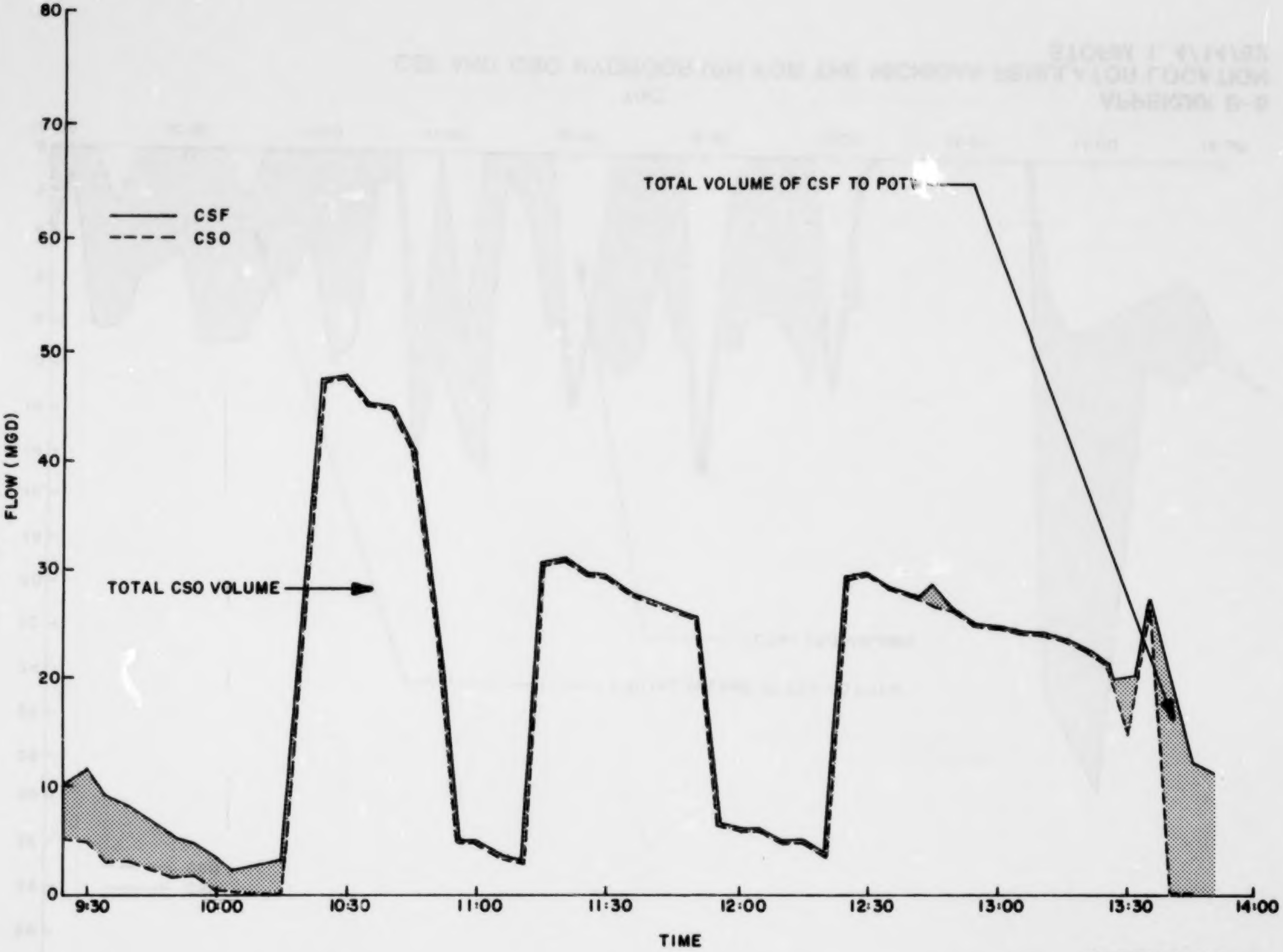
APPENDIX B-4
CSF AND CSO HYDROGRAPH AT
DEXTER/HUNTINGTON REGULATOR LOCATION
STORM 2, 8/25/82



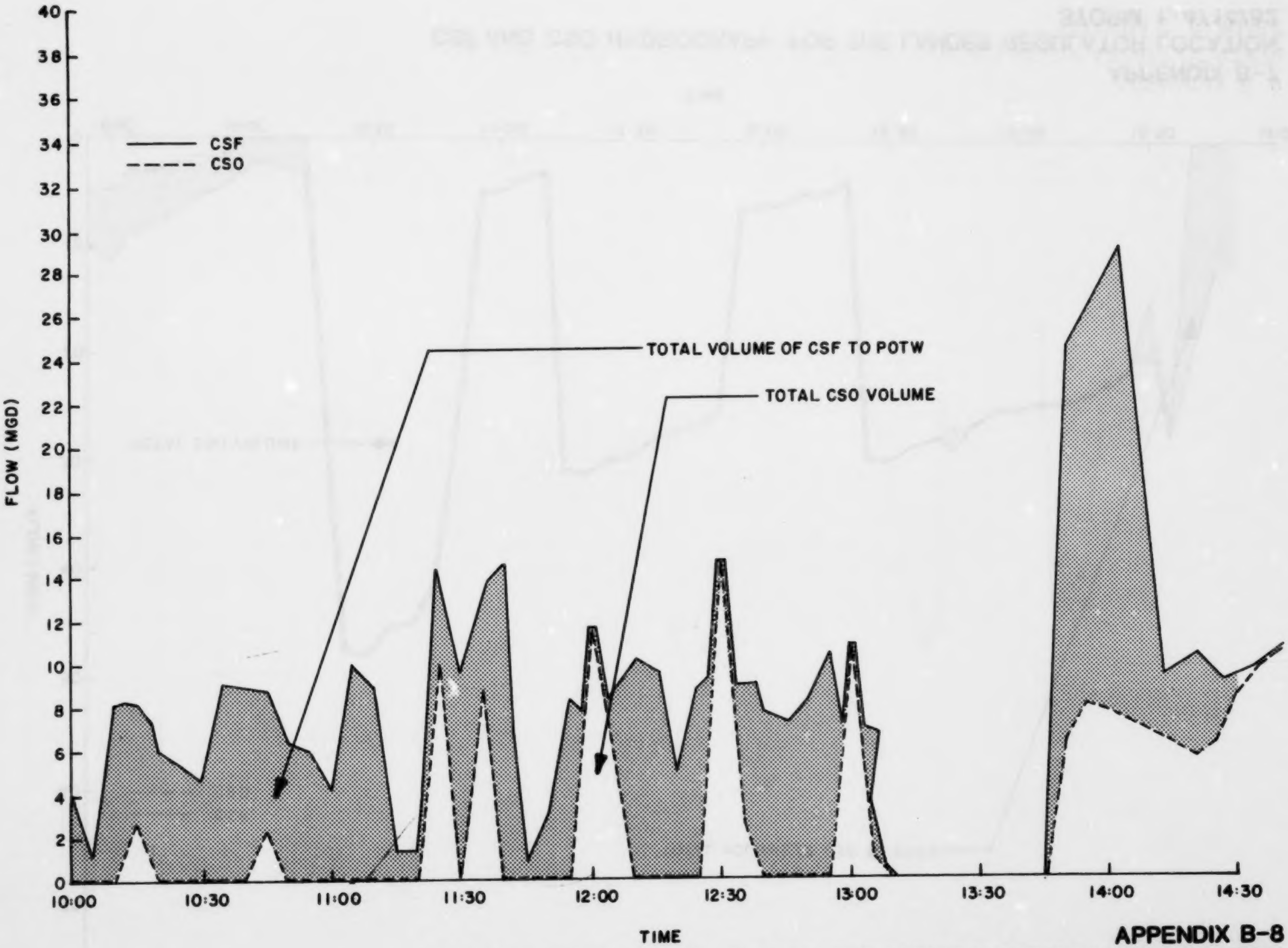
APPENDIX B-5
CSF AND CSO HYDROGRAPH AT ERNEST/ALLENS REGULATOR
STORM 3, 9/20/82



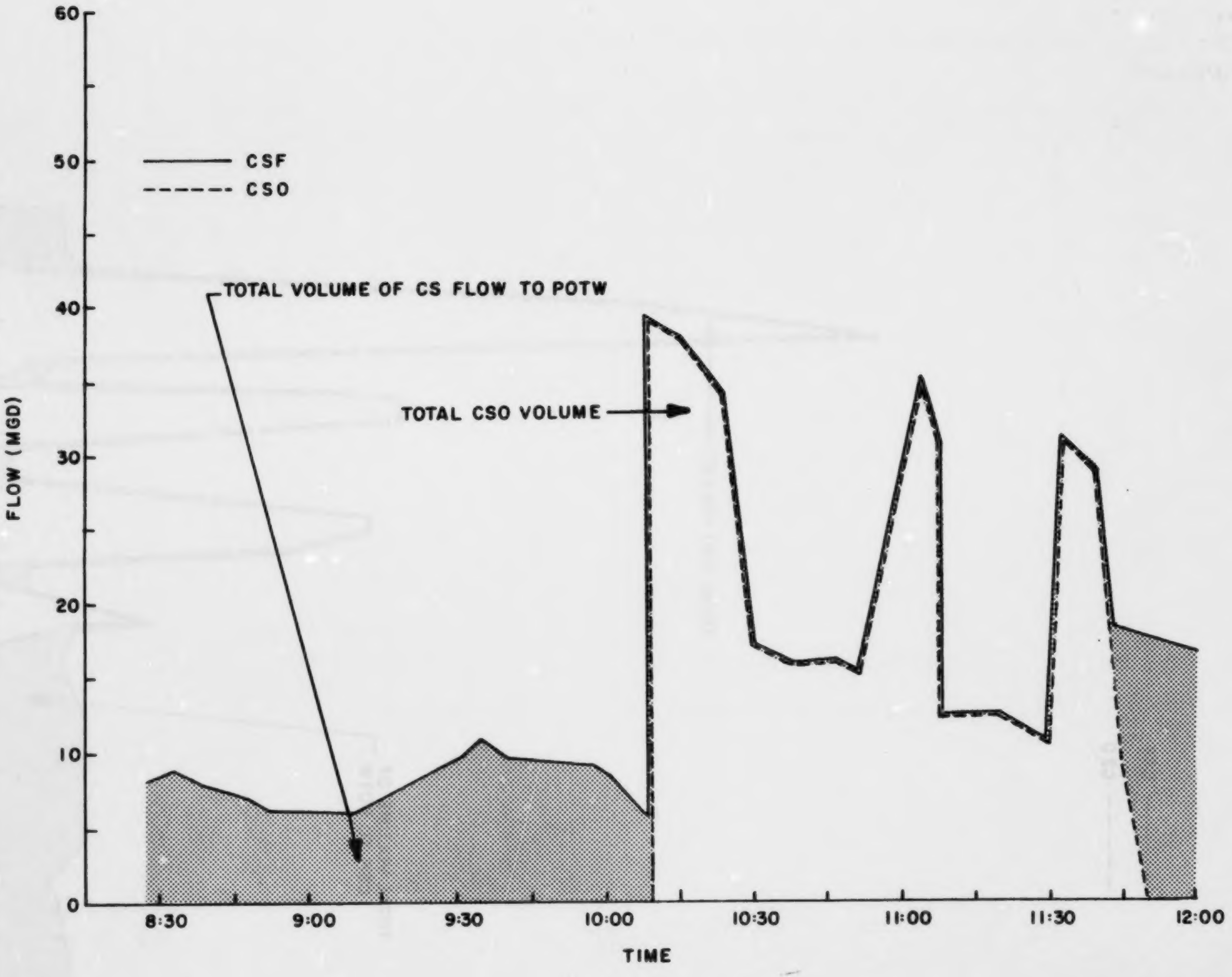
APPENDIX B-6
CSF AND CSO HYDROGRAPH FOR THE DEXTER/HUNTINGTON REGULATOR LOCATION
STORM 3, 9/20/82



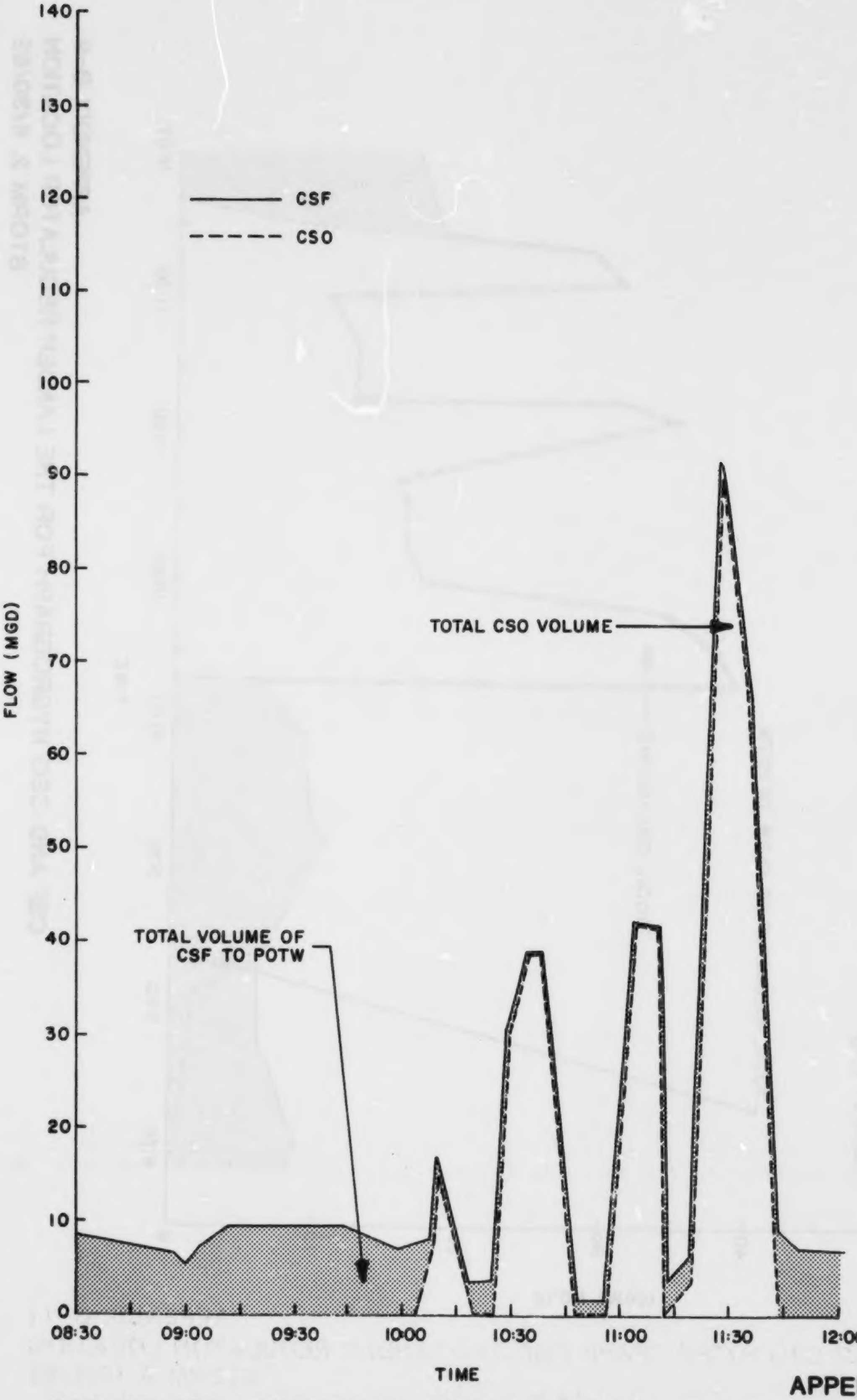
APPENDIX B-7
CSF AND CSO HYDROGRAPH FOR THE LANDER REGULATOR LOCATION
STORM 1, 4/14/82



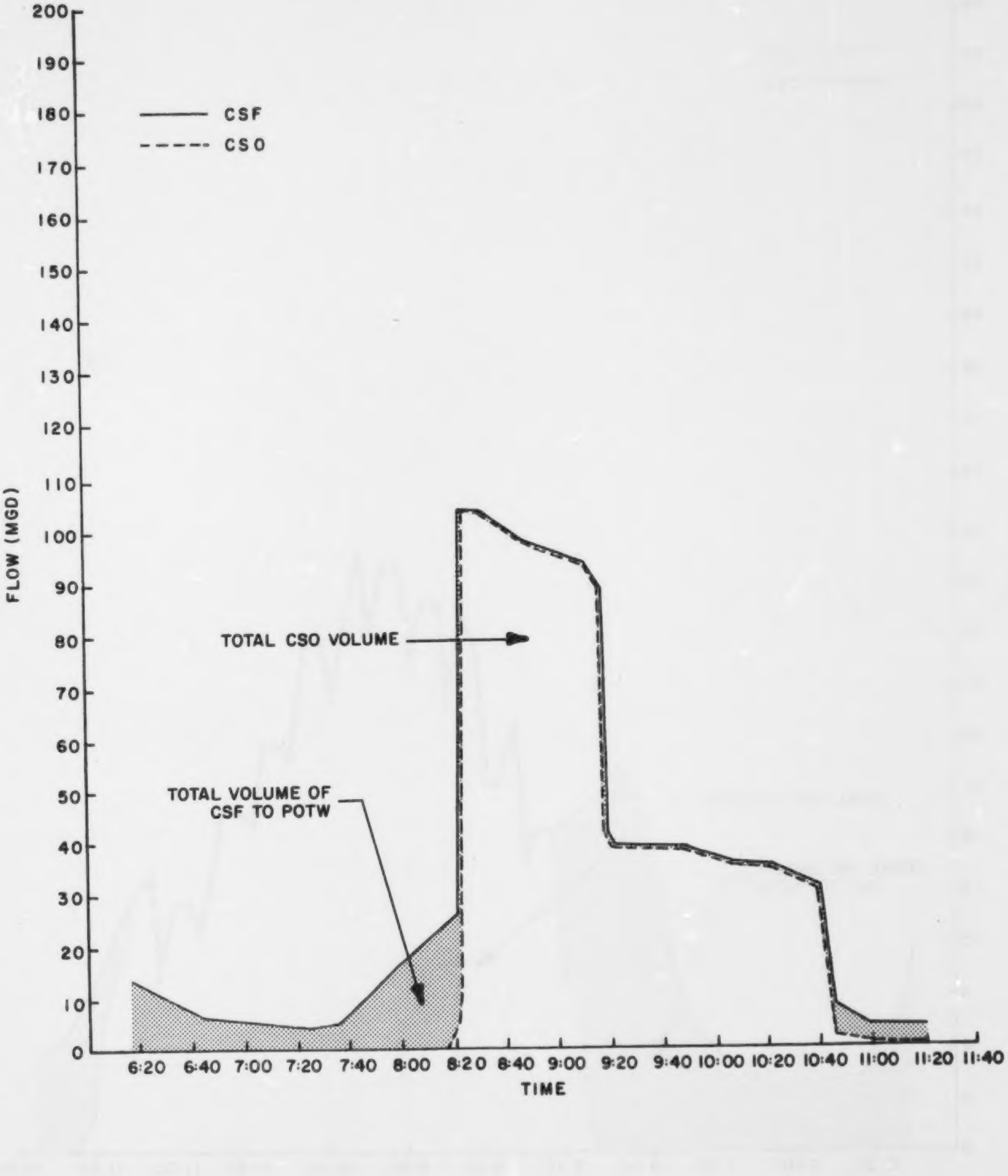
APPENDIX B-8
CSF AND CSO HYDROGRAPH FOR THE MICHIGAN REGULATOR LOCATION
STORM 1, 4/14/82



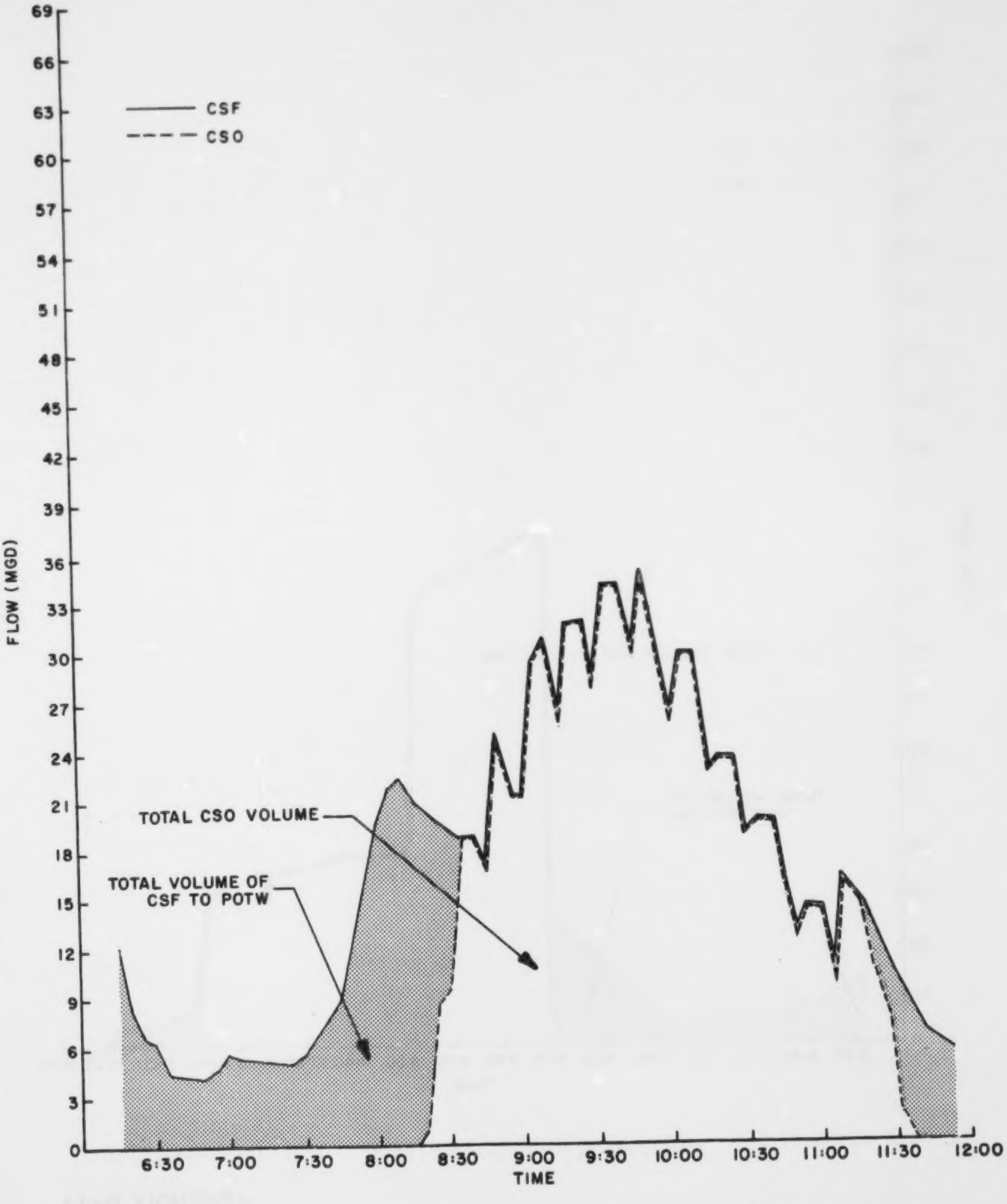
APPENDIX B-9
CSF AND CSO HYDROGRAPH FOR THE LANDER REGULATOR LOCATION
STORM 2, 6/30/82



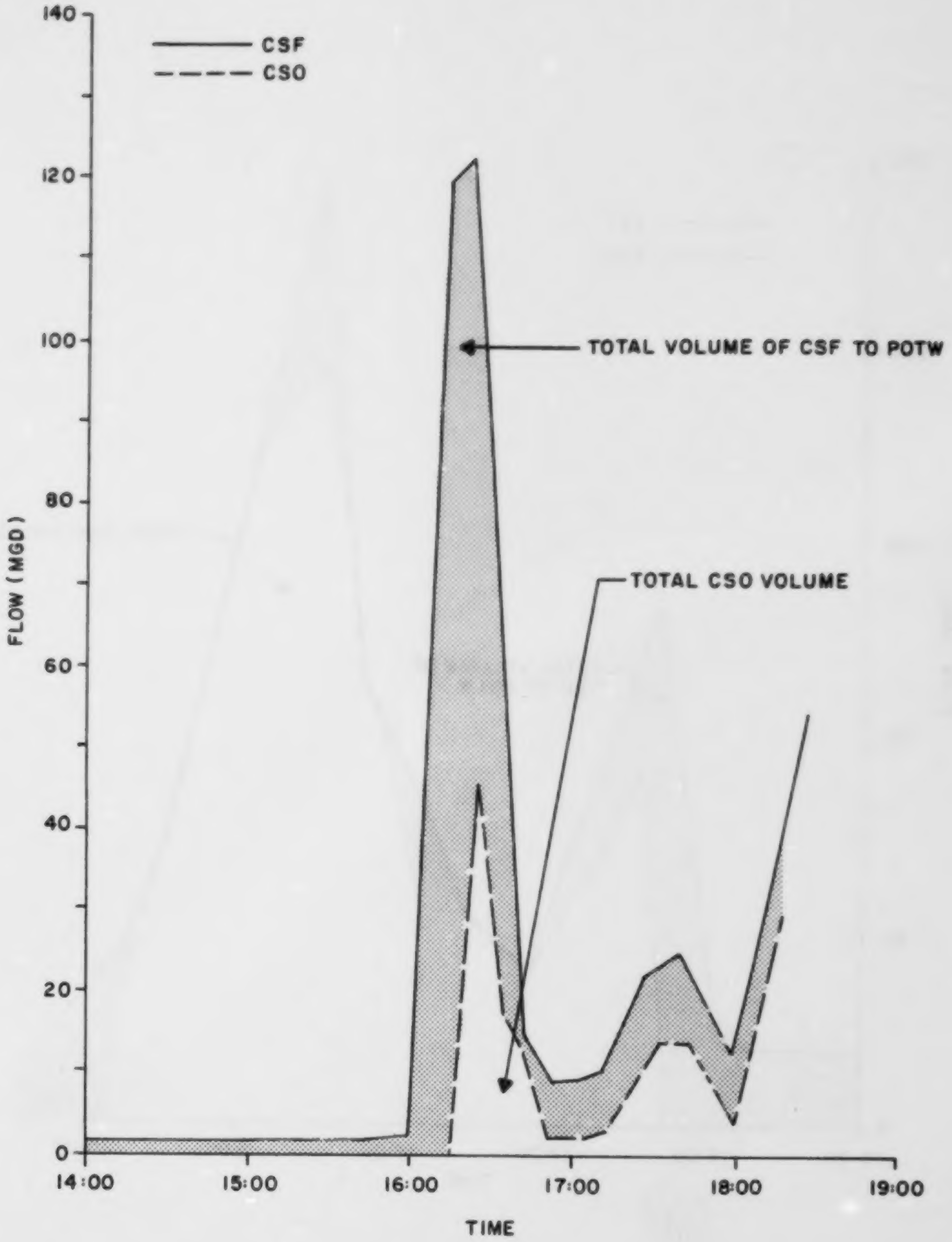
APPENDIX B-10
CSF AND CSO HYDROGRAPH FOR THE MICHIGAN REGULATOR LOCATION
STORM 2, 6/30/82



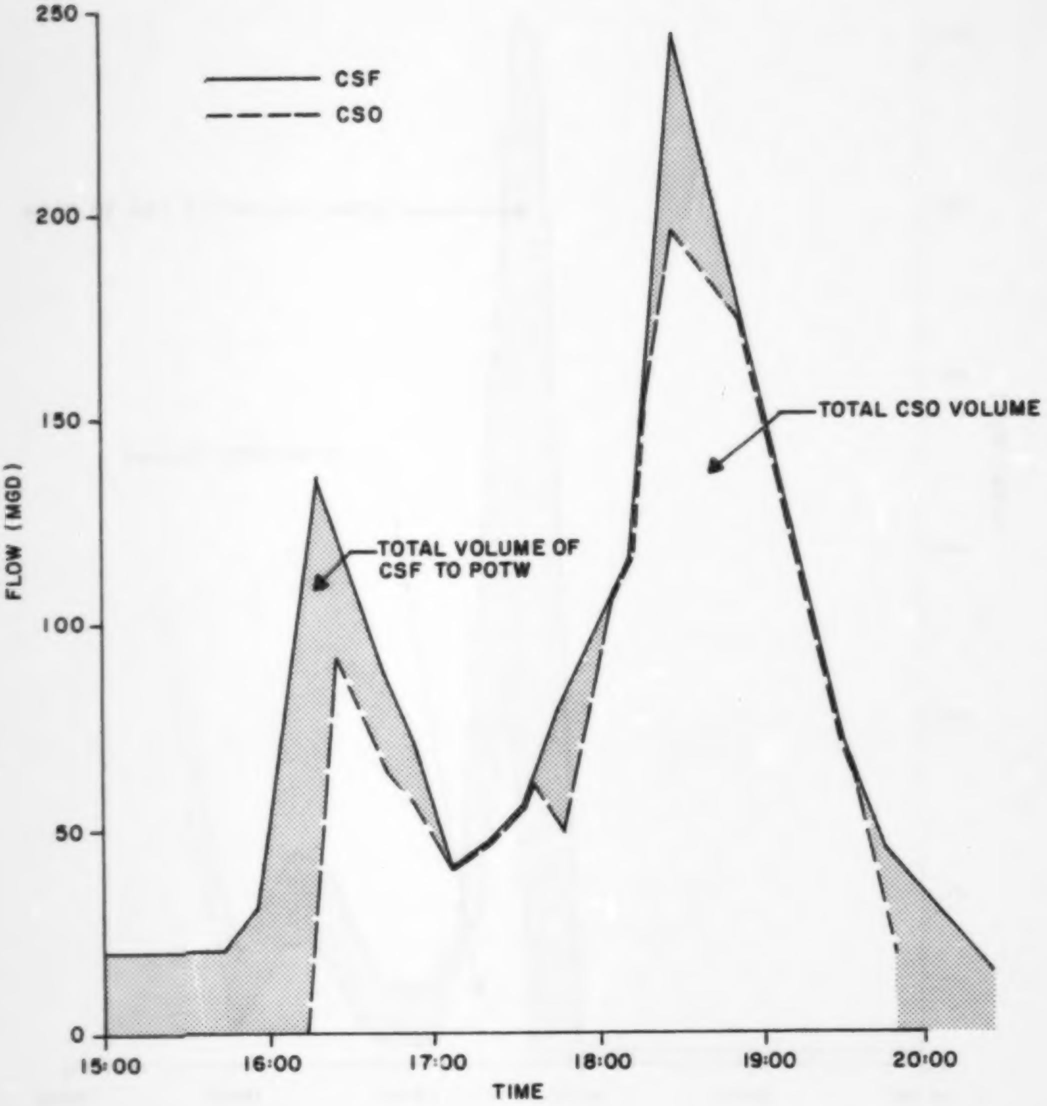
APPENDIX B-11
CSF AND CSO HYDROGRAPH FOR THE LANDER REGULATOR LOCATION
STORM 3, 10/6/82



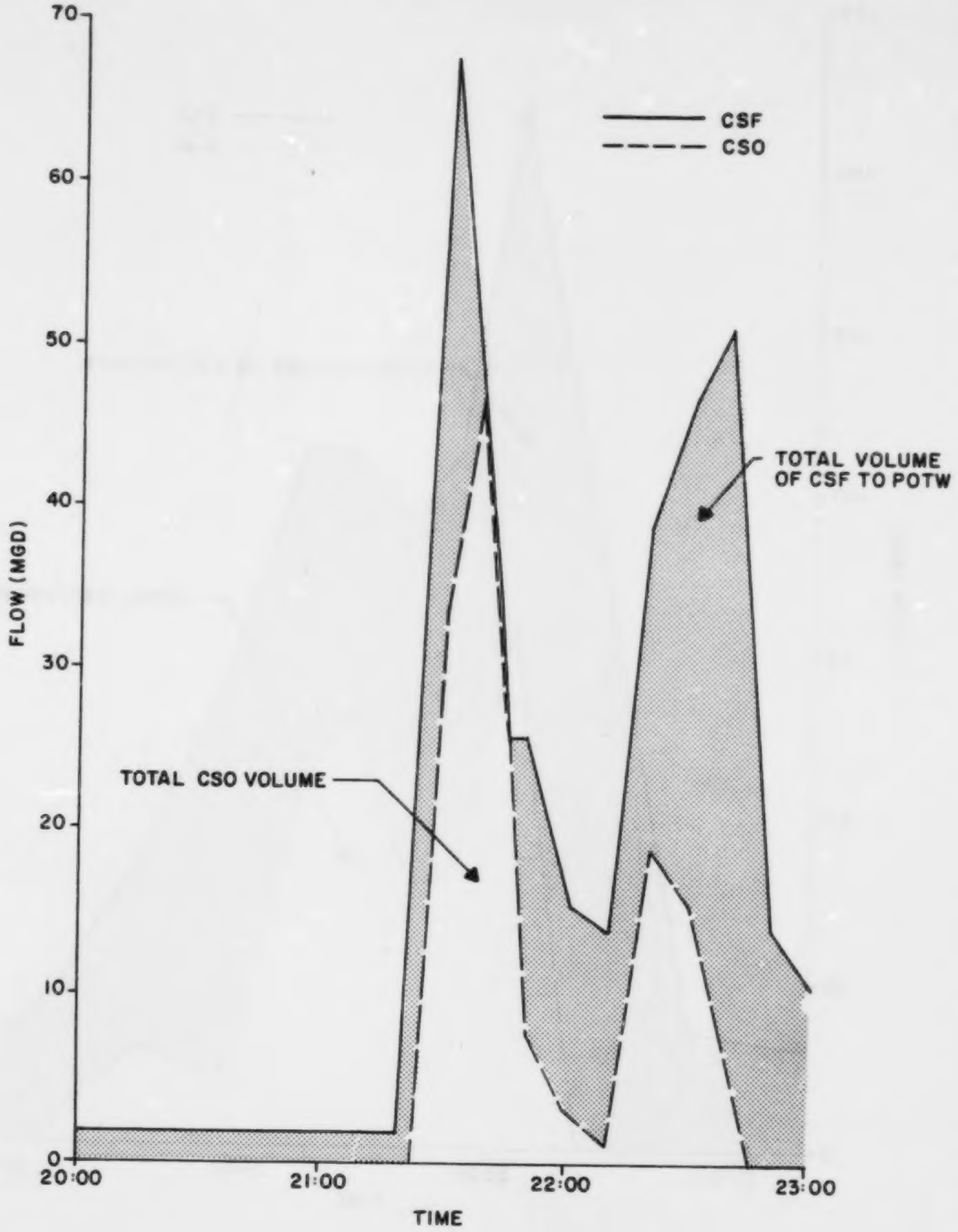
APPENDIX B-12
CSF AND CSO HYDROGRAPH FOR THE MICHIGAN REGULATOR LOCATION
STORM 3, 10/6/82



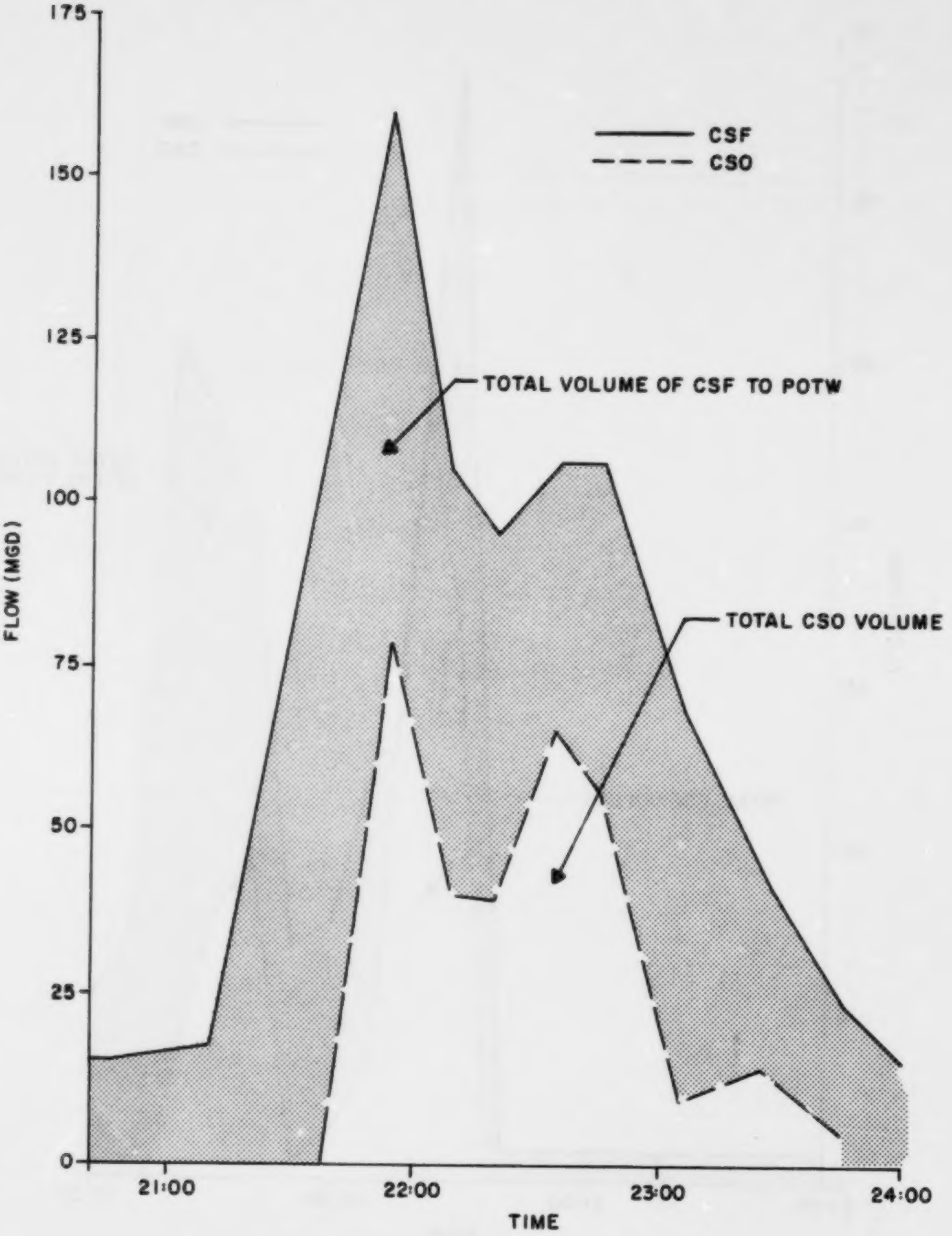
APPENDIX B-13
CSF AND CSO HYDROGRAPH AT PRAIRIE REGULATOR
STORM 1, 10/6/82



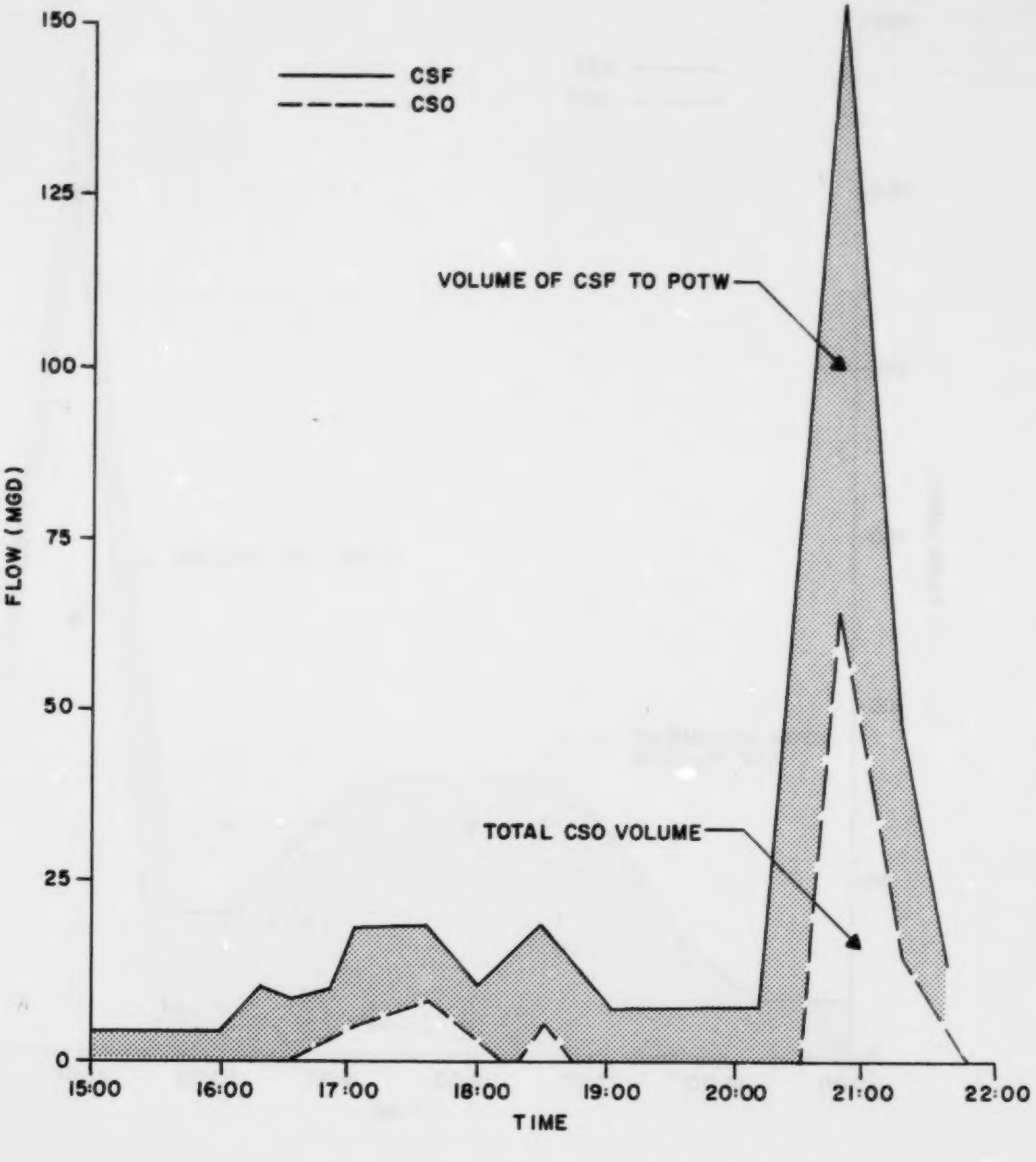
APPENDIX B-14
CSF AND CSO HYDROGRAPH AT BRANCH REGULATOR
STORM 1, 10/6/82



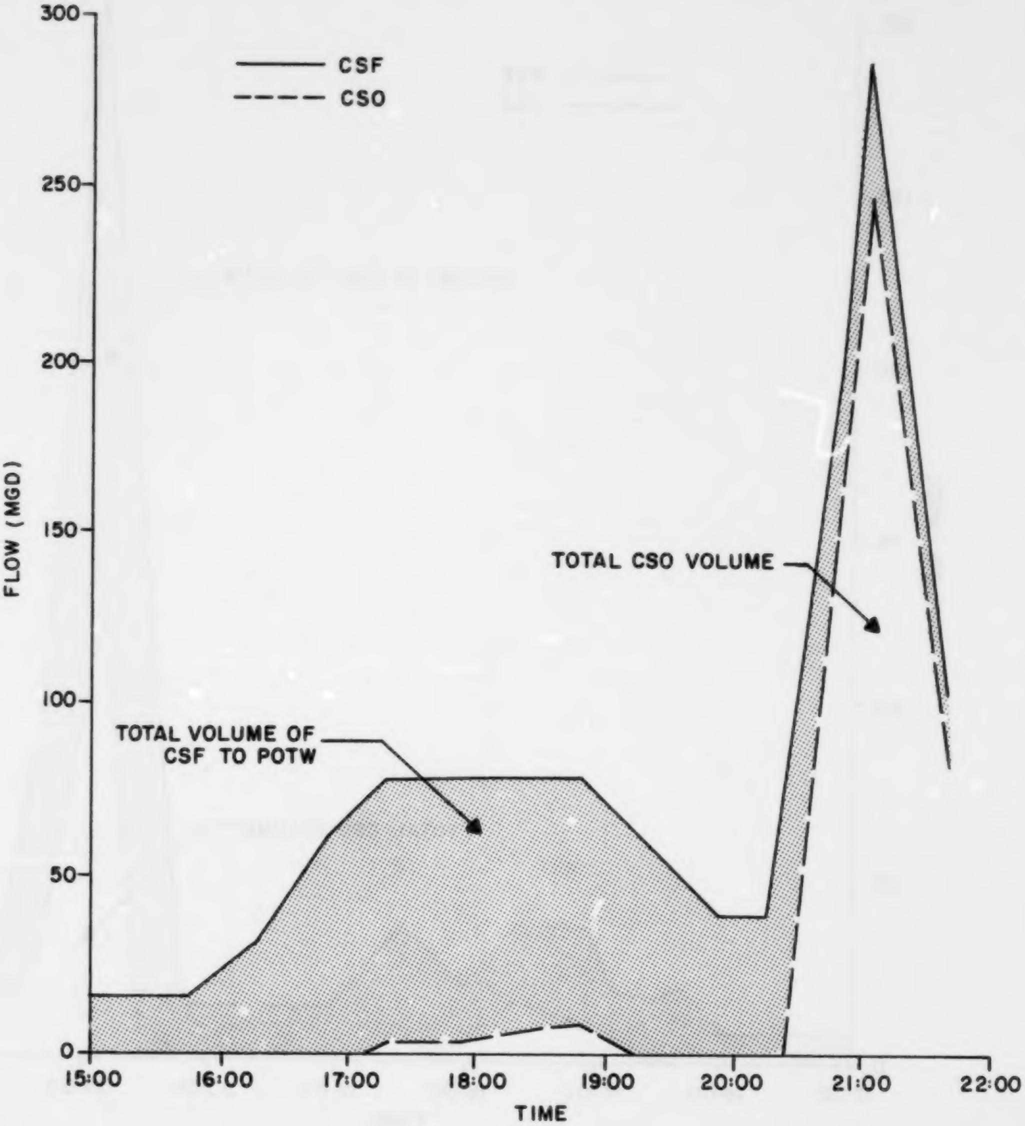
APPENDIX B-15
CSF AND CSO HYDROGRAPH AT PRAIRIE REGULATOR
STORM 2, 10/19/82



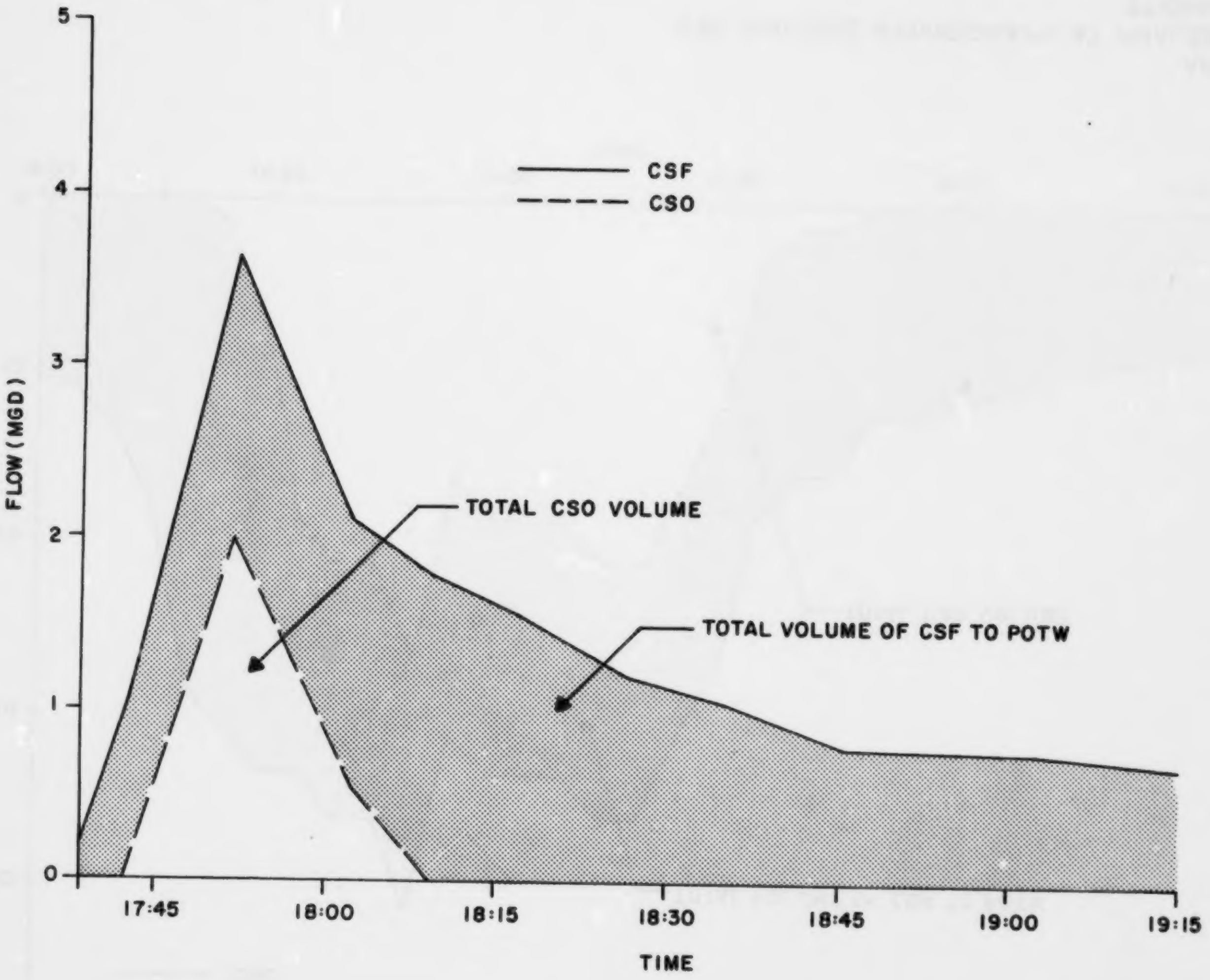
APPENDIX B-16
CSF AND CSO HYDROGRAPH AT BRANCH REGULATOR
STORM 2, 10/19/82



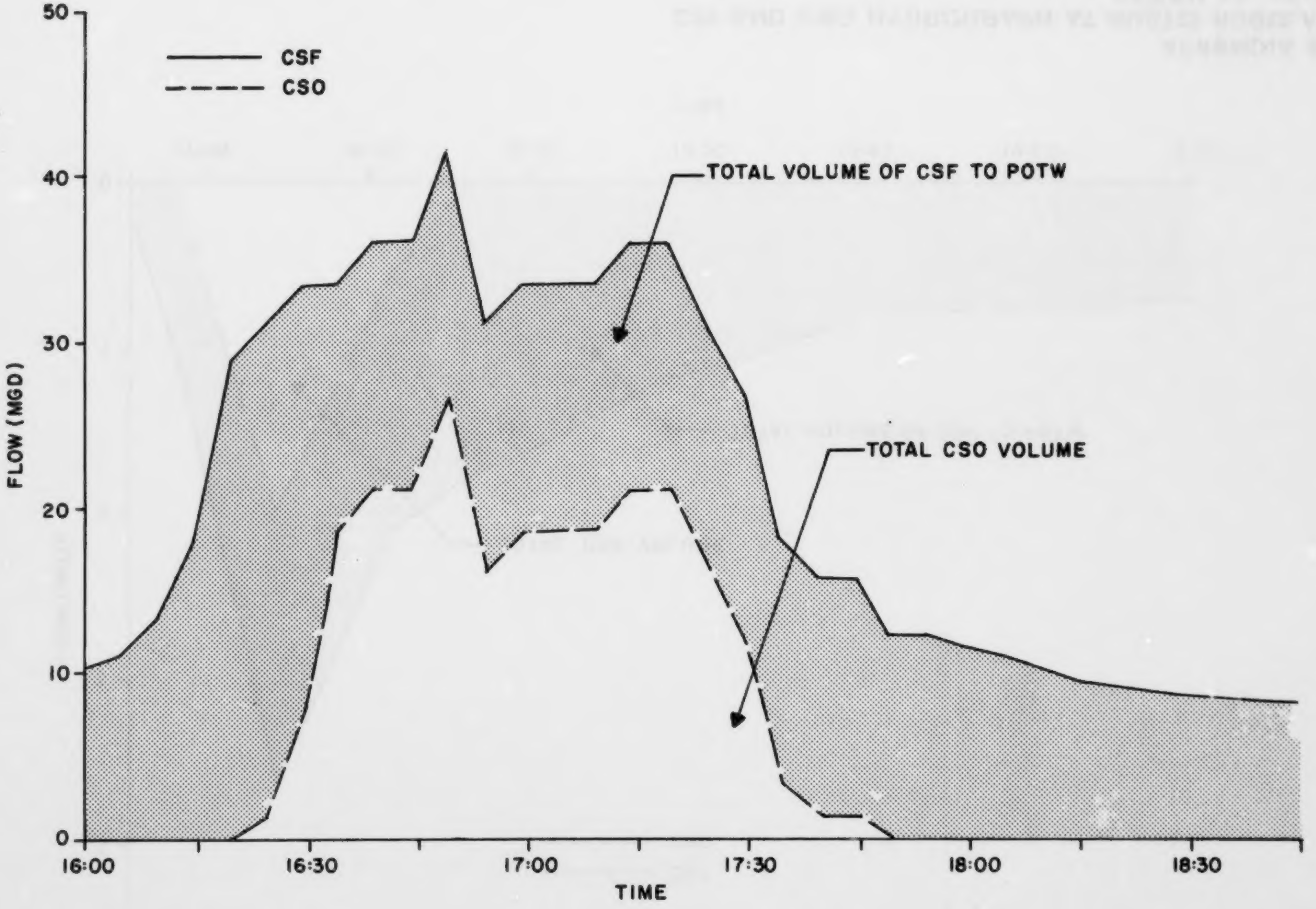
APPENDIX B-17
CSF AND CSO HYDROGRAPH AT PRAIRIE REGULATOR
STORM 3, 12/2/82



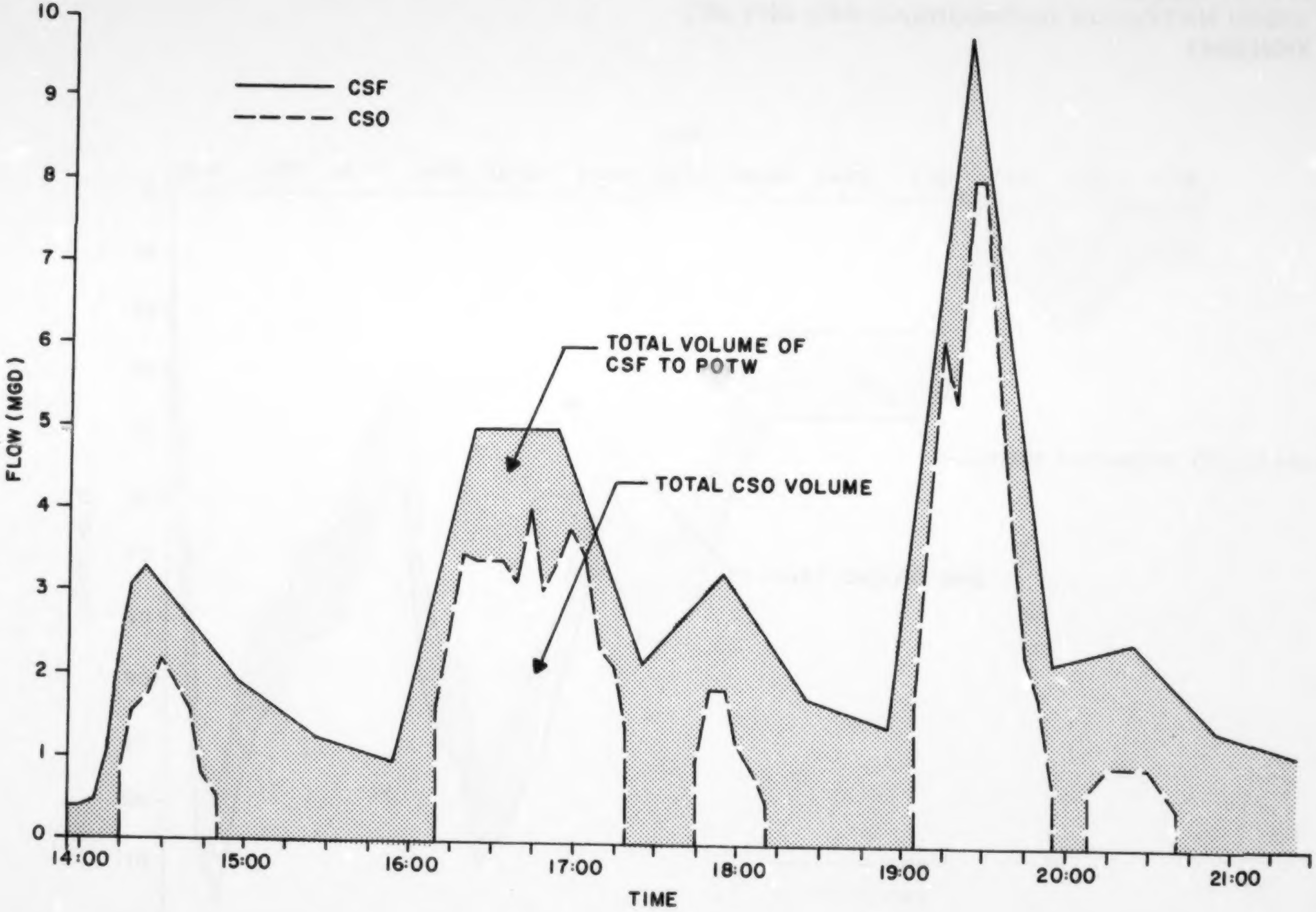
APPENDIX B-18
CSF AND CSO HYDROGRAPH AT BRANCH REGULATOR
STORM 3, 12/2/82



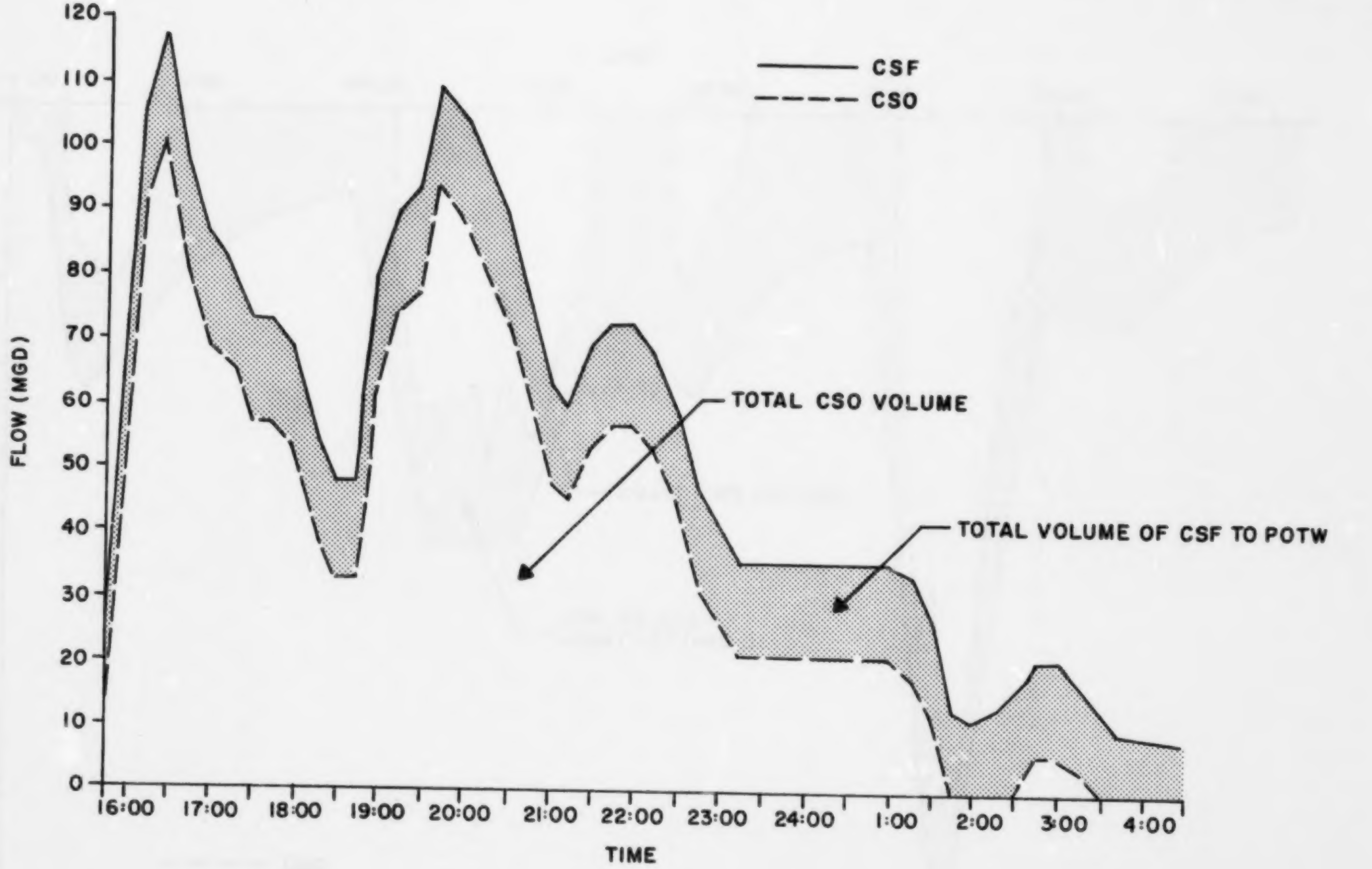
APPENDIX B-19
CSF AND CSO HYDROGRAPH AT EUSTIS REGULATOR
STORM 1A, 10/9/82



APPENDIX B-20
CSF AND CSO HYDROGRAPH AT PHALEN REGULATOR
STORM 1B, 11/9/82



APPENDIX B-21
CSF AND CSO HYDROGRAPH AT EUSTIS REGULATOR
STORM 2A, 11/11/82



APPENDIX B-22
CSF AND CSO HYDROGRAPH AT PHALEN REGULATOR
STORM 1B, 10/19/82

APPENDIX C
RAW DATA RESULTS

Table	Title
C-1	Providence Dry Weather Background Results
C-2	Providence Storm One Results
C-3	Providence Storm Two Results
C-4	Providence Storm Three Results
C-5	Seattle Dry Weather Background Results
C-6	Seattle Storm One Results
C-7	Seattle Storm Two Results
C-8	Seattle Storm Three Results
C-9	St. Louis Dry Weather Background Results
C-10	St. Louis Storm One Results
C-11	St. Louis Storm Two Results
C-12	St. Louis Storm Three Results
C-13	St. Paul Dry Weather Background Results
C-14	St. Paul Storm One Results
C-15	St. Paul Storm Two Results
C-16	Sediment Results

TABLE C-01
PROVIDENCE, R.I. DRY WEATHER COMPOSITE

POLLUTANT	UNITS	E3A DW BKGD 11044	D3H DW HKGD 11045	E3A TAP WATER 11046
CONVENTIONAL/NONCONVENTIONAL				
BIOCHEMICAL OXYGEN DEMAND	MG/L	40.0	115.0	10.0 LT
CHEMICAL OXYGEN DEMAND	MG/L	157.0	260.0	50.0 LT
TOTAL ORGANIC CARBON	MG/L	30.5	40.5	5.0
TOTAL SOLIDS	MG/L	323.0	373.0	78.0
TOTAL VOLATILE SOLIDS	MG/L	129.0	203.0	28.0
TOTAL VOL SUS SOLIDS	MG/L	30.0	112.0	67.0
TOTAL SUSPENDED SOLIDS	MG/L	43.0	123.0	4.0 LT
TOTAL VOL DIS SOLIDS	MG/L	99.0	83.0	1.0 LT
TOTAL DISSOLVED SOLIDS	MG/L	285.0	244.0	24.0
SETTLEABLE SOLIDS	ML/L	1.0 LT	1.0 LT	13.0
CHLORIDE	MG/L	25.0	28.0	.2
AMMONIA NITROGEN	MG/L	2.3	7.1	10.0 LT
TOTAL PHENOL	UG/L	13.0	46.0	5.0 LT
OIL AND GREASE	MG/L	7.0	24.0	10.0 LT
METALS				
ANTIMONY	UG/L	5.0 LT	5.0 LT	5.0 LT
ARSENIC	UG/L	3.0 LT	3.0 LT	3.0 LT
BERYLLIUM	UG/L	2.0 LT	2.0 LT	2.0 LT
CADMIUM	UG/L	5.0 LT	5.0 LT	5.0 LT
CHROMIUM	UG/L	7670.0	2150.0	7.0
COPPER	UG/L	3010.0	1020.0	14.0
LEAD	UG/L	55.0 LT	75.0	55.0 LT
MERCURY	UG/L	1.0 LT	1.0 LT	1.0 LT
NICKEL	UG/L	7620.0	841.0	35.0 LT
SELENIUM	UG/L	3.0 LT	6.0 LT	3.0
SILVER	UG/L	73.0	47.0	96.0
THALLIUM	UG/L	50.0 LT	50.0 LT	50.0 LT
ZINC	UG/L	1180.0	744.0	4.0 LT
OTHERS				
CYANIDE	UG/L	3300.0	28.0	20.0 LT
NONCONVENTIONAL METALS				
ALUMINUM	UG/L	949.0	555.0	100.0
BARIUM	UG/L	15.0	33.0	7.0
BORON	UG/L	1580.0	383.0	27.0 LT
CALCIUM	UG/L	11600.0	14100.0	8520.0
COBALT	UG/L	12.0 LT	12.0 LT	12.0 LT

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NS = NOT SAMPLED
POLLUTANTS NOT LISTED WERE NOT DETECTED

TABLE C-01
PROVIDENCE, R.I. DRY WEATHER COMPOSITE

POLLUTANT	UNITS	E9A DW BKGD 11044	D9H DW BKGD 11045	E9A TAP WATER 11046
IRON	UG/L	1420.0	1220.0	244.0
MAGNESIUM	UG/L	1230.0	1910.0	571.0
MANGANESE	UG/L	63.0	35.0	4.0
MOLYBDENUM	UG/L	38.0	46.0	26.0
SODIUM	UG/L	31800.0	4700.0	7980.0
TIN	UG/L	1540.0	952.0	460.0
TITANIUM	UG/L	34.0	14.0	2.0 LT
VANADIUM	UG/L	5.0 LT	5.0 LT	5.0 LT
YTTRIUM	UG/L	2.0 LT	3.0	2.0 LT
VOLATILE_ORGANICS__________				
CARBON TETRACHLORIDE	UG/L	ND	ND	4.0
CHLOROFORM	UG/L	5.0	5.7	10.5
TOLUENE	UG/L	210.0	20.3	ND
ETHYLBENZENE	UG/L	2.0	ND	ND
METHYLENE CHLORIDE	UG/L	8.0	222.7	11.0
TETRACHLOROETHENE	UG/L	70.0	ND	ND
1,1-DICHLOROETHANE	UG/L	3.0	ND	ND
1,1-DICHLOROETHENE	UG/L	2.0	1.0	ND
1,1,1-TRICHLOROETHANE	UG/L	717.0	227.0	ND
TRANS-1,2-DICHLOROETHENE	UG/L	ND	203.6	ND
VINYL CHLORIDE	UG/L	ND	12.7	ND
TRICHLOROETHENE	UG/L	227.0	75.7	ND
SEMI-VOLATILE_BASE/NEUTRALS_				
SEMIVOLATILE_ACID__________				
PESTICIDE_EXTRACTABLES______				

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TABLE C-02
PROVIDENCE. R.I.   STORM EVENT ONE

POLLUTANT	UNITS	E@A WW BKGD 11047	E@A CSF 11048	E@A CSO 11049	E@A FIRST FLUSH 11050	E@A RUNOFF 11051	E@A PRECIP 11057
CONVENTIONAL/NONCONVENTIONAL							
BIOCHEMICAL OXYGEN DEMAND	MG/L	20.0	11.0 LT	11.0 LT	45.0	6.0 LT	10.0 LT
CHEMICAL OXYGEN DEMAND	MG/L	50.0 LT	50.0 LT	50.0 LT	230.0	50.0 LT	50.0 LT
TOTAL ORGANIC CARBON	MG/L	26.5	40.0	37.0	NS	23.5	8.0
NON-PARTICULATE TOC	MG/L	NS	NS	NS	56.0	NS	NS
TOTAL SOLIDS	MG/L	201.0	129.0	150.0	283.0	111.0	37.0
TOTAL VOLATILE SOLIDS	MG/L	41.0	NS	68.0	163.0	NS	24.0
TOTAL VOL SUS SOLIDS	MG/L	23.0	NS	26.0	70.0	NS	4.0 LT
TOTAL SUSPENDED SOLIDS	MG/L	27.0	46.0	48.0	149.0	50.0	4.0 LT
TOTAL VOL DIS SOLIDS	MG/L	18.0	48.0	42.0	93.0	10.0 LT	18.0
TOTAL DISSOLVED SOLIDS	MG/L	174.0	83.0	102.0	134.0	61.0	35.0
SETTLEABLE SOLIDS	ML/L	1.0 LT	1.0 LT	1.0 LT	2.7	1.0 LT	1.0 LT
CHLORIDE	MG/L	22.8	5.7	5.5	8.1	2.4	1.9
AMMONIA NITROGEN	MG/L	1.0 LT	1.3	1.5	2.7	1.0 LT	1.0 LT
TOTAL PHENOL	UG/L	22.0	31.0	34.0	15.0	5.0 LT	5.0 LT
OIL AND GREASE	MG/L	4.2	4.9	6.3	18.3	5.0 LT	5.0 LT
METALS______________________							
ANTIMONY	UG/L	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT
ARSENIC	UG/L	3.0 LT	3.0 LT	3.0 LT	3.0 LT	3.0 LT	3.0 LT
BERYLLIUM	UG/L	6.0	6.0	6.0	7.0	6.0	6.0
CADMIUM	UG/L	12.0	4.0	10.0	15.0	6.0	3.0
CHROMIUM	UG/L	1300.0	169.0	140.0	94.0	53.0	9.0
COPPER	UG/L	2300.0	427.0	342.0	635.0	94.0	24.0
LEAD	UG/L	157.0	603.0	629.0	853.0	409.0	110.0
MERCURY	UG/L	1.0 LT	1.0 LT	1.0 LT	1.0 LT	1.0 LT	1.0 LT
NICKEL	UG/L	5250.0	1630.0	1310.0	1390.0	73.0	40.0 LT
SELENIUM	UG/L	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT
SILVER	UG/L	10.0	7.0	31.0	31.0	7.0 LT	19.0
THALLIUM	UG/L	104.0	100.0 LT	109.0	188.0	100.0 LT	100.0 LT
ZINC	UG/L	1100.0	555.0	464.0	879.0	230.0	17.0
OTHERS______________________							
CYANIDE	UG/L	3850.0	20.0 LT	20.0 LT	52.0	20.0 LT	20.0 LT
NONCONVENTIONAL METALS______							
ALUMINUM	UG/L	2000.0	914.0	1010.0	2860.0	1550.0	164.0
BARIUM	UG/L	19.0	41.0	42.0	92.9	35.0	7.0
BORON	UG/L	889.0	122.0	92.0	155.0	34.0 LT	34.0 LT
CALCIUM	UG/L	11200.0	5680.0	4680.0	9600.0	3390.0	645.0

LT = LESS THAN
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POLLUTANTS NOT LISTED WERE NOT DETECTED

TABLE C-02
PROVIDENCE, R.I.   STORM EVENT ONE

POLLUTANT	UNITS	E&A WW BKGD 11047	E&A CSF 11048	E&A CSO 11049	E&A FIRST FLUSH 11050	E&A RUNOFF 11051	E&A PRECIP 11057
COBALT	UG/L	16.0	7.0 LT	16.0	27.0	9.0	12.0
IRON	UG/L	1170.0	2110.0	1870.0	7180.0	2170.0	298.0
MAGNESIUM	UG/L	1180.0	767.0	643.0	1700.0	545.0	86.0
MANGANESE	UG/L	68.0	88.0	79.0	165.0	64.0	8.0
MOLYBDENUM	UG/L	25.0 LT	25.0 LT	25.0 LT	25.0 LT	25.0 LT	25.0 LT
SODIUM	UG/L	29600.0	4560.0	11500.0	13000.0	4420.0	3520.0
TIN	UG/L	2600.0	715.0 LT	715.0 LT	1630.0	715.0 LT	715.0 LT
TITANIUM	UG/L	7.0	40.0	34.0	157.0	70.0	11.0
VANADIUM	UG/L	16.0 LT	16.0 LT	16.0 LT	16.0 LT	16.0 LT	16.0 LT
YTTRIUM	UG/L	4.0	3.0	7.0	10.0	7.0	5.0
VOLATILE ORGANICS							
CHLOROFORM	UG/L	3.1	1.7	1.6	1.8	1.7	1.7
TOLUENE	UG/L	5.6	4.1	4.6	6.2	ND	ND
METHYLENE CHLORIDE	UG/L	12.2	18.6	15.5	8.2	8.8	8.5
TETRACHLOROETHENE	UG/L	182.0	22.7	20.0	83.0	ND	2.7
1.1-DICHLOROETHANE	UG/L	1.3	2.9	3.0	1.4	2.5	1.9
1.1.1-TRICHLOROETHANE	UG/L	37.2	8.5	8.7	6.9	ND	ND
TRANS-1.2-DICHLOROETHENE	UG/L	ND	ND	ND	3.8	ND	ND
TRICHLOROETHENE	UG/L	215.0	19.0	23.0	28.3	ND	ND
SEMI-VOLATILE BASE/NEUTRALS							
PYRENE	UG/L	ND	ND	ND	89.0	ND	ND
BIS(2-ETHYLHEXYL)PHTHALATE	UG/L	22.6	14.7	3.9	8.4	ND	ND
SEMIVOLATILE ACID							
PENTACHLOROPHENOL	UG/L	ND	ND	ND	ND	119.0	ND
PESTICIDE EXTRACTABLES							

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TABLE C-02
PROVIDENCE. R.I. STORM EVENT ONE

POLLUTANT	UNITS	DOH WW BKGD 11063	DOH CSF 11064	DOH CSO 11065	DOH FIRST FLUSH 11066	DOH RUNOFF 11067	DOH PRECIP 11068
CONVENTIONAL/NONCONVENTIONAL							
BIOCHEMICAL OXYGEN DEMAND	MG/L	25.0	100.0	130.0	230.0	17.0 LT	17.0 LT
CHEMICAL OXYGEN DEMAND	MG/L	50.0 LT	260.0	290.0	600.0	75.0	50.0 LT
TOTAL ORGANIC CARBON	MG/L	28.0	NS	NS	NS	NS	10.0
NON-PARTICULATE TOC	MG/L	NS	42.0	44.5	56.0	29.5	NS
TOTAL SOLIDS	MG/L	162.0	347.0	252.0	578.0	131.0	10.0 LT
TOTAL VOLATILE SOLIDS	MG/L	50.0	254.0	174.0	426.0	78.0	10.0 LT
TOTAL VOL SUS SOLIDS	MG/L	18.0	188.0	126.0	362.0	34.0	4.0 LT
TOTAL SUSPENDED SOLIDS	MG/L	28.0	245.0	170.0	462.0	81.0	4.0 LT
TOTAL VOL DIS SOLIDS	MG/L	32.0	66.0	48.0	64.0	44.0	10.0 LT
TOTAL DISSOLVED SOLIDS	MG/L	134.0	102.0	82.0	116.0	50.0	10.0 LT
SETTLEABLE SOLIDS	ML/L	1.0 LT	14.0	5.0	9.0	1.0 LT	1.0 LT
CHLORIDE	MG/L	22.0	10.0	8.6	12.0	4.1	2.9
AMMONIA NITROGEN	MG/L	7.3	3.7	3.2	5.1	1.0 LT	1.0 LT
TOTAL PHENOL	UG/L	8.0	25.0	42.0	66.0	18.0	10.0
OIL AND GREASE	MG/L	5.0 LT	27.4	30.4	46.9	5.0 LT	5.0 LT
METALS							
ANTIMONY	UG/L	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT
ARSENIC	UG/L	3.0 LT	3.0 LT	3.0 LT	3.0 LT	3.0 LT	3.0 LT
BERYLLIUM	UG/L	7.0	8.0	8.0	9.0	9.0	8.0
CADMIUM	UG/L	7.0	10.0	15.0	15.0	12.0	7.0
CHROMIUM	UG/L	20.0	34.0	48.0	53.0	30.0	20.0
COPPER	UG/L	63.0	358.0	344.0	525.0	105.0	18.0
LEAD	UG/L	176.0	574.0	538.0	623.0	683.0	141.0
MERCURY	UG/L	1.0 LT	1.0 LT	1.0 LT	1.0 LT	1.0 LT	1.0 LT
NICKEL	UG/L	64.0	248.0	281.0	438.0	134.0	40.0 LT
SELENIUM	UG/L	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT
SILVER	UG/L	7.0	7.0 LT	23.0	19.0	19.0	7.0
THALLIUM	UG/L	100.0 LT	100.0 LT	100.0 LT	100.0 LT	100.0 LT	100.0 LT
ZINC	UG/L	79.0	576.0	622.0	1050.0	411.0	9.0 LT
OTHERS							
CYANIDE	UG/L	35.0	20.0 LT	20.0 LT	20.0 LT	20.0 LT	20.0 LT
NONCONVENTIONAL METALS							
ALUMINUM	UG/L	115.0	2350.0	1480.0	2250.0	1640.0	89.0
BARIUM	UG/L	31.0	88.0	84.0	158.0	78.0	7.0
BORON	UG/L	34.0 LT	35.0	50.0	52.0	70.0	34.0 LT
CALCIUM	UG/L	16900.0	8550.0	8310.0	13200.0	4590.0	865.0

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TABLE C-02
PROVIDENCE, R.I. STORM EVENT ONE

POLLUTANT	UNITS	D&H WW BKGD 11063	D&H CSF 11064	D&H CSO 11065	D&H FIRST FLUSH 11066	D&H RUNOFF 11067	D&H PRECIP 11068
COBALT	UG/L	16.0	21.0	34.0	30.0	22.0	12.0
IRON	UG/L	1340.0	2840.0	2650.0	4330.0	2230.0	112.0
MAGNESIUM	UG/L	2080.0	1610.0	1540.0	2220.0	1010.0	219.0
MANGANESE	UG/L	36.0	79.0	78.0	107.0	83.0	4.0
MOLYBDENUM	UG/L	25.0 LT	25.0 LT	52.0	121.0	25.0 LT	53.0
SODIUM	UG/L	22300.0	18400.0	24900.0	25300.0	17500.0 LT	8960.0
TIN	UG/L	2460.0	1230.0	1370.0	2120.0	1050.0	715.0 LT
TITANIUM	UG/L	4.0	38.0	41.0	44.0	80.0	3.0
VANADIUM	UG/L	16.0 LT	82.0	91.0	150.0	148.0	80.0
YTTRIUM	UG/L	4.0	6.0	10.0	6.0	8.0	3.0
VOLATILE ORGANICS							
TOLUENE	UG/L	2.0	5.4	5.5	13.0	ND	ND
ETHYLBENZENE	UG/L	1.8	ND	ND	2.1	ND	ND
METHYLENE CHLORIDE	UG/L	20.0	26.0	25.0	23.0	18.0	20.0
TETRACHLOROETHENE	UG/L	124.0	568.0	682.0	11.4	ND	ND
1,1-DICHLOROETHENE	UG/L	2.0	ND	ND	ND	ND	ND
1,1,1-TRICHLOROETHANE	UG/L	100.0	50.0	53.0	83.0	ND	ND
1,1,2-TRICHLOROETHANE	UG/L	ND	2.9	3.0	2.0	ND	ND
TRANS-1,2-DICHLOROETHENE	UG/L	153.0	207.0	253.0	572.0	ND	ND
VINYL CHLORIDE	UG/L	44.0	1.5	2.8	8.1	ND	ND
TRICHLOROETHENE	UG/L	103.0	285.0	366.0	574.0	ND	ND
SEMI-VOLATILE BASE/NEUTRALS							
BIS(2-ETHYLHEXYL)PHTHALATE	UG/L	11.8	35.0	36.0	42.0	19.0	7.2
SEMIVOLATILE ACID							
PHENOL	UG/L	ND	ND	ND	20.0	ND	ND
PESTICIDE EXTRACTABLES							

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TABLE C-03
PROVIDENCE. R.I.   STORM EVENT TWO

POLLUTANT	UNITS	E@A WW BKGD 11058	E@A CSF 11059	E@A CSO 11060	E@A FIRST FLUSH 11061	E@A RUNOFF 11062	E@A PRECIP 11079
CONVENTIONAL/NONCONVENTIONAL							
BIOCHEMICAL OXYGEN DEMAND	MG/L	18.0 LT	18.0 LT	18.0 LT	26.0	18.0 LT	18.0
CHEMICAL OXYGEN DEMAND	MG/L	76.0	50.0 LT	50.0 LT	120.0	50.0 LT	50.0 LT
TOTAL ORGANIC CARBON	MG/L	49.0	35.5	29.0	66.0	24.0	11.0
TOTAL SOLIDS	MG/L	384.0	233.0	190.0	354.0	98.0	56.0
TOTAL VOLATILE SOLIDS	MG/L	99.0	73.0	67.0	125.0	57.0	15.5
TOTAL VOL SUS SOLIDS	MG/L	17.0	22.0	15.0	20.0	14.0	4.5
TOTAL SUSPENDED SOLIDS	MG/L	23.5	36.0	23.0	33.0	28.0	5.5
TOTAL VOL DIS SOLIDS	MG/L	82.0	51.0	52.0	105.0	43.0	11.0
TOTAL DISSOLVED SOLIDS	MG/L	360.5	197.0	167.0	321.0	70.0	50.5
SETTLEABLE SOLIDS	ML/L	1.0 LT	1.0 LT	1.0 LT	1.0 LT	1.0 LT	1.0 LT
CHLORIDE	MG/L	50.0	19.0	15.0	30.0	8.7	1.0
AMMONIA NITROGEN	MG/L	4.2	1.6	1.0 LT	4.2	1.0 LT	1.0 LT
TOTAL PHENOL	UG/L	17.0	16.0	16.0	51.0	32.0	5.0 LT
OIL AND GREASE	MG/L	10.0 LT	6.0	8.0	6.0	5.0 LT	10.0 LT
METALS							
ANTIMONY	UG/L	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT
ARSENIC	UG/L	3.0 LT	3.0 LT	3.0 LT	3.0 LT	3.0 LT	3.0 LT
BERYLLIUM	UG/L	2.0 LT	2.0 LT	2.0 LT	2.0 LT	2.0 LT	2.0 LT
CADMIUM	UG/L	10.0	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT
CHROMIUM	UG/L	2040.0	1190.0	881.0	1890.0	4.0 LT	4.0 LT
COPPER	UG/L	3190.0	1980.0	1460.0	3350.0	209.0	19.0 LT
LEAD	UG/L	120.0 LT	120.0 LT	120.0 LT	120.0 LT	120.0 LT	120.0 LT
MERCURY	UG/L	1.0 LT	1.0 LT	1.0 LT	4.0	1.0 LT	1.0 LT
NICKEL	UG/L	3870.0	7940.0	7160.0	7200.0	525.0	40.0 LT
SELENIUM	UG/L	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT
SILVER	UG/L	158.0	22.0	22.0	7.0 LT	7.0 LT	7.0 LT
THALLIUM	UG/L	70.0 LT	70.0 LT	70.0 LT	70.0 LT	70.0 LT	70.0 LT
ZINC	UG/L	1300.0	1480.0	1020.0	3420.0	216.0	12.0
OTHERS							
CYANIDE	UG/L	10350.0	10300.0	5180.0	16800.0	11900.0	20.0 LT
NONCONVENTIONAL METALS							
ALUMINUM	UG/L	1320.0	654.0	574.0	974.0	439.0	90.0 LT
BARIUM	UG/L	20.0	19.0	20.0	17.0	17.0	2.0 LT
BORON	UG/L	695.0	776.0	722.0	693.0	68.0	20.0 LT
CALCIUM	UG/L	8190.0	5570.0	5420.0	8430.0	1170.0	143.0
COBALT	UG/L	15.0	22.0	17.0	12.0	6.0 LT	6.0 LT

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POLLUTANTS NOT LISTED WERE NOT DETECTED

TABLE C-03
PROVIDENCE, R.I. STORM EVENT TWO

POLLUTANT	UNITS	E@A WW BKGD 11058	E@A CSF 11059	E@A CSO 11060	E@A FIRST FLUSH 11061	E@A RUNOFF 11062	E@A PRECIP 11079
IRON	UG/L	762.0	839.0	627.0	1310.0	1080.0	5.0 LT
MAGNESIUM	UG/L	768.0	653.0	593.0	906.0	387.0	84.0
MANGANESE	UG/L	35.0	33.0	30.0	42.0	29.0	2.0 LT
MOLYBDENUM	UG/L	18.0 LT	18.0 LT	18.0 LT	18.0 LT	18.0 LT	18.0 LT
SODIUM	UG/L	68100.0	31100.0	21000.0	53200.0	120.0 LT	1200.0 LT
TIN	UG/L	510.0 LT	510.0 LT	510.0 LT	510.0 LT	510.0 LT	510.0 LT
TITANIUM	UG/L	7.0	12.0	6.0	12.0	18.0	3.0 LT
VANADIUM	UG/L	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT
YTTRIUM	UG/L	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT
VOLATILE ORGANICS							
CHLOROFORM	UG/L	12.0	ND	ND	ND	ND	ND
TOLUENE	UG/L	5.8	3.5	2.9	5.6	11.3	ND
ETHYLBENZENE	UG/L	5.3	ND	ND	ND	ND	ND
METHYLENE CHLORIDE	UG/L	50473.0	679.0	328.0	1515.0	7.5	2.9
TETRACHLOROETHENE	UG/L	315.0	224.0	195.0	382.0	ND	ND
1,1-DICHLOROETHENE	UG/L	19.0	18.5	ND	ND	ND	ND
1,1,1-TRICHLOROETHANE	UG/L	252.0	127.0	104.0	411.0	ND	ND
1,1,2-TRICHLOROETHANE	UG/L	6.0	2.8	2.6	ND	ND	ND
TRANS-1,2-DICHLOROETHENE	UG/L	5.5	ND	ND	ND	ND	ND
TRICHLOROETHENE	UG/L	766.0	215.0	230.0	288.0	27.0	58.0
SEMI-VOLATILE BASE/NEUTRALS							
BUTYL BENZYL PHTHALATE	UG/L	ND	ND	ND	13.0	9.3	ND
BIS(2-ETHYLHEXYL)PHTHALATE	UG/L	19.0	11.0	12.0	9.0	13.5	13.0
SEMIVOLATILE ACID							
2,4-DIMETHYLPHENOL	UG/L	492.0	ND	ND	ND	ND	ND
PHENOL	UG/L	561.0	ND	ND	ND	ND	ND
PENTACHLOROPHENOL	UG/L	364.0	ND	ND	ND	ND	ND
PESTICIDE EXTRACTABLES							

LT = LESS THAN
GT = GREATER THAN
ND = NOT DETECTED
NS = NOT SAMPLED
POLLUTANTS NOT LISTED WERE NOT DETECTED

TABLE C-03
PROVIDENCE, R.I. STORM EVENT TWO

POLLUTANT	UNITS	D&H WW BKGD 11074	D&H CSF 11075	D&H CSO 11076	D&H FIRST FLUSH 11077	D&H RUNOFF 11078	E&A PRECIP 11079
CONVENTIONAL/NONCONVENTIONAL							
BIOCHEMICAL OXYGEN DEMAND	MG/L	95.0	53.0	90.0 LT	39.0	18.0 LT	18.0
CHEMICAL OXYGEN DEMAND	MG/L	970.0	210.0	290.0	260.0	50.0 LT	50.0 LT
TOTAL ORGANIC CARBON	MG/L	NS	NS	63.0	83.5	21.5	11.0
NON-PARTICULATE TOC	MG/L	84.0	33.5	NS	NS	NS	NS
TOTAL SOLIDS	MG/L	1048.0	333.0	265.0	343.0	138.0	56.0
TOTAL VOLATILE SOLIDS	MG/L	488.0	166.0	153.0	159.0	48.0	15.5
TOTAL VOL SUS SOLIDS	MG/L	236.0	108.0	110.0	57.0	30.0	4.5
TOTAL SUSPENDED SOLIDS	MG/L	298.0	152.0	151.0	82.0	81.0	5.5
TOTAL VOL DIS SOLIDS	MG/L	252.0	58.0	43.0	102.0	18.0	11.0
TOTAL DISSOLVED SOLIDS	MG/L	750.0	181.0	114.0	261.0	57.0	50.5
SETTLEABLE SOLIDS	ML/L	8.8	2.4	4.2	2.0	1.0 LT	1.0 LT
CHLORIDE	MG/L	64.0	19.0	9.2	23.0	.5	1.0
AMMONIA NITROGEN	MG/L	10.0	2.4	1.1	4.9	1.0 LT	1.0 LT
TOTAL PHENOL	UG/L	18.0	23.0	12.0	29.0	5.0 LT	5.0 LT
OIL AND GREASE	MG/L	12.0	35.0	24.0	39.0	10.0 LT	10.0 LT
METALS							
ANTIMONY	UG/L	5.0	4.0 LT	4.0 LT	5.0	4.0 LT	4.0 LT
ARSENIC	UG/L	3.0 LT	3.0 LT	3.0 LT	3.0 LT	3.0 LT	3.0 LT
BERYLLIUM	UG/L	2.0 LT	2.0 LT	2.0 LT	2.0 LT	2.0 LT	2.0 LT
CADMIUM	UG/L	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT
CHROMIUM	UG/L	2850.0	302.0	140.0	601.0	4.0 LT	4.0 LT
COPPER	UG/L	3490.0	1200.0	694.0	1760.0	24.0	19.0 LT
LEAD	UG/L	120.0 LT	240.0	230.0	120.0 LT	283.0	120.0 LT
MERCURY	UG/L	1.0 LT	1.0 LT	1.0 LT	1.0 LT	1.0 LT	1.0 LT
NICKEL	UG/L	2550.0	952.0	549.0	1560.0	40.0 LT	40.0 LT
SELENIUM	UG/L	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT
SILVER	UG/L	14.0	7.0 LT	7.0 LT	7.0 LT	7.0 LT	7.0 LT
THALLIUM	UG/L	70.0 LT	70.0 LT	70.0 LT	70.0 LT	70.0 LT	70.0 LT
ZINC	UG/L	2210.0	1320.0	809.0	1910.0	211.0	12.0
OTHERS							
CYANIDE	UG/L	33000.0	1536.0	694.0	2000.0	20.0 LT	20.0 LT
NONCONVENTIONAL METALS							
ALUMINUM	UG/L	1540.0	1340.0	1180.0	1250.0	1540.0	90.0 LT
BARIUM	UG/L	16.0	31.0	28.0	20.0	47.0	2.0 LT
BORON	UG/L	231.0	185.0	87.0	235.0	59.0	20.0 LT
CALCIUM	UG/L	9440.0	5570.0	3570.0	8210.0	2210.0	143.0

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POLLUTANTS NOT LISTED WERE NOT DETECTED

TABLE C-03
PROVIDENCE. R.I. STORM EVENT TWO

POLLUTANT	UNITS	D&H WW BKGD 11074	D&H CSF 11075	D&H CSO 11076	D&H FIRST FLUSH 11077	D&H RUNOFF 11078	E&A PRECIP 11079
COBALT	UG/L	162.0	8.0	11.0	6.0 LT	6.0 LT	6.0 LT
IRON	UG/L	1150.0	1860.0	1810.0	1290.0	1978.0	5.0 LT
MAGNESIUM	UG/L	1660.0	1000.0	722.0	1310.0	508.0	84.0
MANGANESE	UG/L	21.0	38.0	34.0	37.0	42.0	2.0 LT
MOLYBDENUM	UG/L	18.0 LT	18.0 LT	18.0 LT	18.0 LT	18.0 LT	18.0 LT
SODIUM	UG/L	143000.0	27500.0	13900.0	37500.0	1200.0 LT	1200.0 LT
TIN	UG/L	510.0 LT	510.0 LT	510.0 LT	510.0 LT	510.0 LT	510.0 LT
TITANIUM	UG/L	36.0	60.0	69.0	39.0	94.0	3.0 LT
VANADIUM	UG/L	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT
YTTRIUM	UG/L	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT
VOLATILE ORGANICS							
TOLUENE	UG/L	7.4	3.8	3.2	4.9	ND	ND
BROMOMETHANE	UG/L	240.0	ND	ND	ND	ND	ND
METHYLENE CHLORIDE	UG/L	19.0	41.0	25.0	42.0	6.0	2.9
TETRACHLOROETHENE	UG/L	ND	555.0	455.0	299.0	ND	ND
1.1.1-TRICHLOROETHANE	UG/L	243.0	225.0	93.0	296.0	ND	ND
1.1.2-TRICHLOROETHANE	UG/L	110.0	24.0	16.0	43.0	2.4	ND
TRANS-1.2-DICHLOROETHENE	UG/L	64.0	31.0	22.0	35.0	ND	ND
VINYL CHLORIDE	UG/L	13.0	ND	.5	3.5	ND	ND
TRICHLOROETHENE	UG/L	5855.0	3700.0	1922.0	5143.0	12.0	58.0
SEMI-VOLATILE BASE/NEUTRALS							
ANTHRACENE	UG/L	ND	ND	ND	ND	83.0	ND
DIMETHYLPHTHALATE	UG/L	45.0	ND	ND	ND	ND	ND
BIS(2-ETHYLHEXYL)PHTHALATE	UG/L	103.0	27.0	17.0	28.0	16.0	13.0
DI-N-BUTYL PHTHALATE	UG/L	ND	17.0	9.0	57.0	ND	ND
SEMIVOLATILE ACID							
4-CHLORO-3-METHYLPHENOL	UG/L	ND	ND	ND	43.0	ND	ND
PESTICIDE EXTRACTABLES							

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TABLE C-04
PROVIDENCE. R.I.   STORM EVENT THREE

POLLUTANT	UNITS	D@H #W BKGD 11052	D@H CSF 11053	D@H CSO 11054	D@H FIRST FLUSH 11055	D@H RUNOFF 11056	E@A PRECIP 11080
CONVENTIONAL/NONCONVENTIONAL							
BIOCHEMICAL OXYGEN DEMAND	MG/L	390.0	190.0	210.0	330.0	23.0	17.0 LT
CHEMICAL OXYGEN DEMAND	MG/L	1100.0	420.0	650.0	1080.0	57.0	50.0 LT
TOTAL ORGANIC CARBON	MG/L	NS	NS	NS	NS	NS	5.0 LT
NON-PARTICULATE TOC	MG/L	132.0	47.5	44.0	64.5	23.5	NS
TOTAL SOLIDS	MG/L	1060.0	477.0	775.0	926.0	120.0	23.0
TOTAL VOLATILE SOLIDS	MG/L	874.0	395.0	567.0	697.0	70.0	23.0
TOTAL VOL SUS SOLIDS	MG/L	690.0	292.0	491.0	580.0	23.0	4.0 LT
TOTAL SUSPENDED SOLIDS	MG/L	784.0	376.0	653.0	747.0	49.0	4.0 LT
TOTAL VOL DIS SOLIDS	MG/L	184.0	103.0	76.0	117.0	47.0	22.0
TOTAL DISSOLVED SOLIDS	MG/L	280.0	101.0	122.0	179.0	71.0	22.0
SETTLEABLE SOLIDS	ML/L	10.0	3.5	6.3	4.6	1.0 LT	1.0 LT
CHLORIDE	MG/L	29.0	9.7	8.4	14.0	1.3	1.0 LT
AMMONIA NITROGEN	MG/L	450.0	8.4	3.0	9.1	1.0 LT	1.0 LT
TOTAL PHENOL	UG/L	56.0	9.8	18.0	7.8	11.0	5.0 LT
OIL AND GREASE	MG/L	220.0	93.0	28.0	72.0	5.0 LT	10.0 LT
METALS							
ANTIMONY	UG/L	4.0 LT	5.0	4.0 LT	4.0 LT	4.0 LT	4.0 LT
ARSENIC	UG/L	3.0 LT	3.0 LT	3.0 LT	3.0 LT	3.0 LT	3.0 LT
BERYLLIUM	UG/L	2.0 LT	2.0 LT	2.0 LT	2.0 LT	2.0 LT	2.0 LT
CADMIUM	UG/L	21.0	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT
CHROMIUM	UG/L	90.0	50.0	27.0	55.0	5.0	4.0 LT
COPPER	UG/L	1260.0	595.0	398.0	587.0	51.0	19.0 LT
LEAD	UG/L	448.0	279.0	290.0	388.0	285.0	120.0 LT
MERCURY	UG/L	5.0	1.0 LT	1.0 LT	1.0 LT	1.0 LT	1.0 LT
NICKEL	UG/L	5560.0	483.0	419.0	564.0	90.0 LT	90.0 LT
SELENIUM	UG/L	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT
SILVER	UG/L	14.0	10.0	8.0	18.0	7.0 LT	7.0 LT
THALLIUM	UG/L	70.0 LT	70.0 LT	70.0 LT	70.0 LT	70.0 LT	70.0 LT
ZINC	UG/L	1440.0	1090.0	1140.0	1350.0	373.0	24.0
OTHERS							
CYANIDE	UG/L	720.0	210.0	160.0	220.0	20.0 LT	20.0 LT
NONCONVENTIONAL METALS							
ALUMINUM	UG/L	1860.0	1640.0	1560.0	2070.0	974.0	90.0 LT
BARIUM	UG/L	89.0	58.0	49.0	76.0	37.0	2.0 LT
BORON	UG/L	153.0	87.0	71.0	97.0	37.0	20.0 LT
CALCIUM	UG/L	13800.0	8580.0	6520.0	8840.0	3130.0	15.0 LT

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TABLE C-04

PROVIDENCE, R.I.   STORM EVENT THREE

POLLUTANT	UNITS	D&H WW BKGD 11052	D&H CSF 11053	D&H CSO 11054	D&H FIRST FLUSH 11055	D&H RUNOFF 11056	E&A PRECIP 11080
COBALT	UG/L	42.0	6.0	6.0 LT	6.0 LT	6.0 LT	6.0 LT
IRON	UG/L	4470.0	3600.0	2650.0	3720.0	1280.0	5.0 LT
MAGNESIUM	UG/L	20100.0	1470.0	1210.0	1600.0	651.0	5.0 LT
MANGANESE	UG/L	114.0	85.0	74.0	93.0	69.0	2.0
MOLYBDENUM	UG/L	18.0 LT	18.0 LT	18.0 LT	18.0 LT	18.0 LT	18.0 LT
SODIUM	UG/L	35000.0	11100.0	6890.0	12600.0	2250.0	1200.0 LT
TIN	UG/L	510.0 LT	510.0 LT	510.0 LT	510.0 LT	510.0 LT	510.0 LT
TITANIUM	UG/L	65.0	58.0	58.0	80.0	52.0	3.0 LT
VANADIUM	UG/L	14.0	15.0	5.0 LT	5.0 LT	5.0 LT	5.0 LT
YTTRIUM	UG/L	6.0	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT
VOLATILE ORGANICS							
CHLOROFORM	UG/L	7.0	ND	ND	ND	ND	ND
TOLUENE	UG/L	30.0	24.0	25.0	30.0	ND	2.0
ETHYLBENZENE	UG/L	11.0	10.0	10.0	14.0	ND	ND
METHYLENE CHLORIDE	UG/L	14.0	12.0	15.0	15.0	6.5	24.0
TETRACHLOROETHENE	UG/L	463.0	474.0	337.0	282.0	ND	ND
1,1,1-TRICHLOROETHANE	UG/L	181.0	239.0	257.0	261.0	ND	ND
1,1,2-TRICHLOROETHANE	UG/L	8.0	9.0	11.0	10.0	ND	ND
1,1,2,2-TETRACHLOROETHANE	UG/L	ND	ND	ND	8.0	ND	ND
TRANS-1,2-DICHLOROETHENE	UG/L	22.0	52.0	48.0	43.0	ND	ND
TRICHLOROETHENE	UG/L	802.0	556.0	546.0	558.0	ND	ND
SEMI-VOLATILE BASE/NEUTRALS							
DIMETHYLPHTHALATE	UG/L	49.0	28.0	ND	ND	ND	ND
PHENANTHRENE	UG/L	8.6	5.7	5.1	6.0	ND	ND
1,4-DICHLOROBENZENE	UG/L	8.0	ND	ND	ND	ND	ND
NAPHTHALENE	UG/L	57.0	17.0	12.0	22.0	ND	ND
BIS(2-ETHYLHEXYL)PHTHALATE	UG/L	73.0	11.0	36.0	14.0	ND	ND
DI-N-BUTYL PHTHALATE	UG/L	22.0	30.0	9.0	39.0	ND	ND
SEMIVOLATILE ACID							
PHENOL	UG/L	17.0	ND	ND	ND	ND	ND
PESTICIDE EXTRACTABLES							

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TABLE C-04

PROVIDENCE. R.I.   STORM EVENT THREE

POLLUTANT	UNITS	E@A WW BKGD 11069	E@A CSF 11070	E@A CSU 11071	E@A FIRST FLUSH 11072	E@A RUNOFF 11073	E@A PRECIP 11080
CONVENTIONAL/NONCONVENTIONAL							
BIOCHEMICAL OXYGEN DEMAND	MG/L	50.0	28.0	17.0	42.0	17.0 LT	17.0 LT
CHEMICAL OXYGEN DEMAND	MG/L	63.0	65.0	55.0	170.0	50.0 LT	50.0 LT
TOTAL ORGANIC CARBON	MG/L	NS	NS	49.0	NS	18.5	5.0 LT
NON-PARTICULATE TOC	MG/L	43.0	25.0	NS	37.0	NS	NS
TOTAL SOLIDS	MG/L	354.0	134.0	82.0	173.0	70.0	23.0
TOTAL VOLATILE SOLIDS	MG/L	139.0	118.0	37.0	51.0	53.0	23.0
TOTAL VOL SUS SOLIDS	MG/L	24.0	57.0	16.0	36.0	9.0	4.0 LT
TOTAL SUSPENDED SOLIDS	MG/L	32.0	68.0	24.0	66.0	23.0	4.0 LT
TOTAL VOL DIS SOLIDS	MG/L	115.0	61.0	21.0	15.0	44.0	22.0
TOTAL DISSOLVED SOLIDS	MG/L	322.0	66.0	58.0	107.0	47.0	22.0
SETTLEABLE SOLIDS	ML/L	1.0 LT	1.0 LT	1.0 LT	1.0 LT	1.0 LT	1.0 LT
CHLORIDE	MG/L	43.0	6.1	3.0	5.5	1.4	1.0 LT
AMMONIA NITROGEN	MG/L	3.5	1.6	1.4	2.7	1.8	1.0 LT
TOTAL PHENOL	UG/L	27.0	32.0	5.0 LT	5.3	5.0 LT	5.0 LT
OIL AND GREASE	MG/L	10.0 LT	5.5	5.0 LT	19.0	5.0 LT	10.0 LT
METALS							
ANTIMONY	UG/L	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT
ARSENIC	UG/L	3.0 LT	3.0 LT	3.0 LT	3.0 LT	3.0 LT	3.0 LT
BERYLLIUM	UG/L	2.0 LT	2.0 LT	2.0 LT	2.0 LT	2.0 LT	2.0 LT
CADMIUM	UG/L	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT
CHROMIUM	UG/L	3660.0	53.0	30.0	54.0	4.0 LT	4.0 LT
COPPER	UG/L	3930.0	229.0	153.0	287.0	238.0	19.0 LT
LEAD	UG/L	120.0 LT	120.0	120.0 LT	235.0	120.0 LT	120.0 LT
MERCURY	UG/L	1.0 LT	1.0 LT	1.0 LT	1.0 LT	1.0 LT	1.0 LT
NICKEL	UG/L	12000.0	470.0	818.0	527.0	153.0	90.0 LT
SELENIUM	UG/L	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT
SILVER	UG/L	119.0	7.0 LT	7.0 LT	7.0 LT	7.0 LT	7.0 LT
THALLIUM	UG/L	70.0 LT	70.0 LT	70.0 LT	70.0 LT	70.0 LT	70.0 LT
ZINC	UG/L	54.0	423.0	350.0	690.0	320.0	24.0
OTHERS							
CYANIDE	UG/L	37000.0	330.0	140.0	400.0	32.0	20.0 LT
NONCONVENTIONAL METALS							
ALUMINUM	UG/L	385.0	448.0	411.0	1050.0	388.0	90.0 LT
BARIUM	UG/L	12.0	12.0	10.0	29.0	27.0	2.0 LT
BORON	UG/L	1460.0	158.0	107.0	177.0	40.0	20.0 LT
CALCIUM	UG/L	9780.0	4240.0	3280.0	6280.0	2580.0	15.0 LT

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POLLUTANTS NOT LISTED WERE NOT DETECTED

TABLE C-04

PROVIDENCE. R.I. STORM EVENT THREE

POLLUTANT	UNITS	E@A WW BKGD 11069	E@A CSF 11070	E@A CSO 11071	E@A FIRST FLUSH 11072	E@A RUNOFF 11073	E@A PRECIP 11080
COBALT	UG/L	22.0	984.0	6.0 LT	6.0 LT	6.0 LT	6.0 LT
IRON	UG/L	680.0		717.0	1910.0	592.0	5.0 LT
MAGNESIUM	UG/L	818.0	546.0	462.0	902.0	432.0	5.0 LT
MANGANESE	UG/L	28.0	55.0	53.0	92.0	46.0	2.0
MOLYBDENUM	UG/L	18.0 LT	18.0 LT	18.0 LT	18.0 LT	18.0 LT	18.0 LT
SODIUM	UG/L	65100.0	1720.0	1200.0 LT	5690.0	1200.0 LT	1200.0 LT
TIN	UG/L	510.0 LT	510.0 LT	510.0 LT	510.0 LT	510.0 LT	510.0 LT
TITANIUM	UG/L	5.0	10.0	8.0	33.0	15.0	3.0 LT
VANADIUM	UG/L	5.0 LT	5.0 LT	5.0 LT	5.0	5.0 LT	5.0 LT
YTTRIUM	UG/L	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT
VOLATILE ORGANICS							
CARBON TETRACHLORIDE	UG/L	ND	14.0	ND	ND	ND	ND
BROMOFORM	UG/L	ND	15.0	ND	ND	ND	ND
CHLOROFORM	UG/L	6.0	ND	ND	ND	ND	ND
TOLUENE	UG/L	3120.0	32.0	12.0	43.0	76.0	2.0
ACRYLONITRILE	UG/L	ND	15.0	ND	ND	ND	ND
BENZENE	UG/L	6.0	ND	ND	ND	ND	ND
CHLOROBENZENE	UG/L	ND	18.0	ND	ND	ND	ND
ETHYLBENZENE	UG/L	10.0	ND	ND	ND	ND	ND
METHYLENE CHLORIDE	UG/L	ND	5.0	29.0	59.0	7.0	24.0
TETRACHLOROETHENE	UG/L	114.0	21.0	16.0	20.0	ND	ND
1.1-DICHLOROETHANE	UG/L	ND	37.0	ND	ND	ND	ND
1.1-DICHLOROETHENE	UG/L	ND	21.0	ND	ND	ND	ND
1.1.1-TRICHLOROETHANE	UG/L	1111.0	454.0	449.0	584.0	ND	ND
1.1.2-TRICHLOROETHANE	UG/L	ND	ND	ND	ND	2.2	ND
1.2-DICHLOROETHANE	UG/L	ND	16.0	ND	ND	ND	ND
1.2-DICHLOROPROPANE	UG/L	ND	22.0	ND	ND	ND	ND
TRANS-1.2-DICHLOROETHENE	UG/L	ND	ND	ND	2.0	ND	ND
TRICHLOROETHENE	UG/L	119.0	28.0	22.0	25.0	ND	ND
SEMI-VOLATILE BASE/NEUTRALS							
N-NITROSODIPHENYLAMINE	UG/L	75.0	ND	ND	ND	ND	ND
BIS(2-ETHYLHEXYL)PHTHALATE	UG/L	16.0	10.0	ND	ND	ND	ND
SEMIVOLATILE ACID							
4-CHLORO-3-METHYLPHENOL	UG/L	ND	121.0	ND	ND	ND	ND
2-CHLOROPHENOL	UG/L	ND	38.0	ND	ND	ND	ND
2-NITROPHENOL	UG/L	ND	92.0	ND	ND	ND	ND
2.4-DICHLOROPHENOL	UG/L	ND	81.0	ND	ND	ND	ND
2.4-DIMETHYLPHENOL	UG/L	ND	83.0	ND	ND	ND	ND

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TABLE C-04
PROVIDENCE. R.I. STORM EVENT THREE

POLLUTANT	UNITS	E@A WW BKGD 11069	E@A CSF 11070	E@A CSO 11071	E@A FIRST FLUSH 11072	E@A RUNOFF 11073	E@A PRECIP 11080
2.4-DINITROPHENOL	UG/L	ND	18.0	ND	ND	ND	ND
2.4.6-TRICHLOROPHENOL	UG/L	ND	80.0	ND	ND	ND	ND
2-METHYL-4.6-DINITROPHENOL	UG/L	ND	41.0	ND	ND	ND	ND
PHENOL	UG/L	14.0	ND	ND	ND	ND	ND
PENTACHLOROPHENOL	UG/L	ND	72.0	ND	ND	ND	ND

PESTICIDE_EXTRACTABLES______

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TABLE C-05

SEATTLE, WA.　　DRY WEATHER COMPOSITE

POLLUTANT	UNITS	LAN DW BKGD 10911	MICH DW BKGD 10912	LAN TAP WATER 10913
CONVENTIONAL/NONCONVENTIONAL				
BIOCHEMICAL OXYGEN DEMAND	MG/L	304.0	106.0	8.0 LT
CHEMICAL OXYGEN DEMAND	MG/L	575.0	215.0	25.0 LT
TOTAL ORGANIC CARBON	MG/L	NS	57.5	5.0 LT
NON-PARTICULATE TOC	MG/L	190.0	NS	NS
TOTAL SOLIDS	MG/L	1360.0	346.0	85.0
TOTAL VOLATILE SOLIDS	MG/L	405.0	131.0	26.0
TOTAL VOL SUS SOLIDS	MG/L	98.0	33.0	4.0
TOTAL SUSPENDED SOLIDS	MG/L	141.0	43.0	4.0
TOTAL VOL DIS SOLIDS	MG/L	307.0	99.0	22.0
TOTAL DISSOLVED SOLIDS	MG/L	1220.0	303.0	81.0
SETTLEABLE SOLIDS	ML/L	3.3	1.0 LT	1.0 LT
CHLORIDE	MG/L	350.0	16.0	3.7
AMMONIA NITROGEN	MG/L	5.8	4.4	1.0 LT
TOTAL PHENOL	UG/L	22.0	8.0	9.0
OIL AND GREASE	MG/L	102.0	27.0	5.0 LT
METALS				
ANTIMONY	UG/L	5.0 LT	5.0 LT	5.0 LT
ARSENIC	UG/L	25.0 LT	25.0 LT	25.0 LT
BERYLLIUM	UG/L	1.0 LT	1.0 LT	1.0 LT
CADMIUM	UG/L	230.0	160.0	5.0 LT
CHROMIUM	UG/L	700.0	34.0	10.0 LT
COPPER	UG/L	1340.0	60.0	58.0
LEAD	UG/L	50.0 LT	50.0 LT	50.0 LT
MERCURY	UG/L	.3 LT	.3 LT	.3 LT
NICKEL	UG/L	2420.0	50.0 LT	50.0 LT
SELENIUM	UG/L	25.0 LT	25.0 LT	25.0 LT
SILVER	UG/L	1.8	3.6	.5 LT
THALLIUM	UG/L	10.0 LT	10.0 LT	10.0 LT
ZINC	UG/L	2610.0	130.0	110.0
OTHERS				
CYANIDE	UG/L	3400.0	140.0	20.0 LT
NONCONVENTIONAL METALS				
ALUMINUM	UG/L	1540.0	770.0	58.0
BARIUM	UG/L	60.0	22.0	10.0 LT
BORON	UG/L	370.0	180.0	20.0 LT
CALCIUM	UG/L	34200.0	20400.0	6050.0

LT = LESS THAN
GT = GREATER THAN
ND = NOT DETECTED
NS = NOT SAMPLED
POLLUTANTS NOT LISTED WERE NOT DETECTED

TABLE C-05

SEATTLE, WA.   DRY WEATHER COMPOSITE

POLLUTANT	UNITS	LAN DW BKGD 10911	MICH DW BKGD 10912	LAN TAP WATER 10913
COBALT	UG/L	5.0 LT	5.0 LT	5.0 LT
IRON	UG/L	6790.0	1980.0	263.0
MAGNESIUM	UG/L	21100.0	7500.0	870.0
MANGANESE	UG/L	380.0	140.0	10.0 LT
MOLYBDENUM	UG/L	10.0 LT	10.0 LT	10.0 LT
SODIUM	UG/L	292000.0	34600.0	2000.0 LT
TIN	UG/L	30.0 LT	30.0 LT	30.0 LT
TITANIUM	UG/L	50.0 LT	50.0 LT	50.0 LT
VANADIUM	UG/L	5.0 LT	5.0 LT	5.0 LT
YTTRIUM	UG/L	5.0 LT	5.0 LT	5.0 LT
VOLATILE ORGANICS				
BROMOFORM	UG/L	13.0	ND	ND
CHLOROFORM	UG/L	26.0	28.0	ND
TOLUENE	UG/L	24.0	78.0	ND
BENZENE	UG/L	12.0	ND	ND
ETHYLBENZENE	UG/L	ND	9.0	ND
METHYLENE CHLORIDE	UG/L	120.0	110.0	ND
TETRACHLOROETHENE	UG/L	ND	13.0	ND
1,1-DICHLOROETHANE	UG/L	48.0	ND	ND
1,1,2-TRICHLOROETHANE	UG/L	16.0	13.0	ND
TRICHLOROETHENE	UG/L	41.0	34.0	ND
SEMI-VOLATILE BASE/NEUTRALS				
SEMIVOLATILE ACID				
PHENOL	UG/L	7.0	15.0	ND
PESTICIDE EXTRACTABLES				

LT = LESS THAN
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POLLUTANTS NOT LISTED WERE NOT DETECTED

TABLE C-06

SEATTLE, WA. STORM EVENT ONE

POLLUTANT	UNITS	LAN WW BKGD 10914	LAN CSF 10915	LAN CSO 10916	LAN FIRST FLUSH 10917	LAN RUNOFF 10918	LAN PRECIP 10924
CONVENTIONAL/NONCONVENTIONAL							
BIOCHEMICAL OXYGEN DEMAND	MG/L	265.0	130.0	124.0	120.0	30.0 LT	30.0 LT
CHEMICAL OXYGEN DEMAND	MG/L	511.0	297.0	348.0	355.0	168.0	25.0 LT
TOTAL ORGANIC CARBON	MG/L	175.0	103.0	111.0	NS	NS	6.0
NON-PARTICULATE TOC	MG/L	NS	NS	NS	73.5	11.5	NS
TOTAL SOLIDS	MG/L	710.0	446.0	486.0	470.0	182.0	10.0 LT
TOTAL VOLATILE SOLIDS	MG/L	305.0	183.0	187.0	190.0	44.0	10.0 LT
TOTAL VOL SUS SOLIDS	MG/L	124.0	65.0	64.0	75.0	36.0	4.0 LT
TOTAL SUSPENDED SOLIDS	MG/L	143.0	128.0	131.0	161.0	113.0	4.0 LT
TOTAL VOL DIS SOLIDS	MG/L	188.0	138.0	129.0	106.0	32.0	10.0 LT
TOTAL DISSOLVED SOLIDS	MG/L	567.0	318.0	358.0	313.0	69.0	10.0 LT
SETTLEABLE SOLIDS	ML/L	4.0	1.0 LT	1.0 LT	1.0 LT	1.0 LT	1.0 LT
CHLORIDE	MG/L	120.0	65.0	87.0	77.0	4.0	1.0
AMMONIA NITROGEN	MG/L	5.4	2.4	2.2	3.2	.2	.1
TOTAL PHENOL	UG/L	25.0	25.0	NS	30.0	7.5	7.5
OIL AND GREASE	MG/L	25.0	8.5	20.5	14.0	7.5	18.0
METALS							
ANTIMONY	UG/L	5.0 LT	5.0 LT	5.0 LT	5.0	11.0	5.0 LT
ARSENIC	UG/L	25.0 LT	25.0 LT	25.0 LT	25.0 LT	28.0	25.0 LT
BERYLLIUM	UG/L	1.0 LT	1.0 LT	1.0 LT	1.0 LT	1.0 LT	1.0 LT
CADMIUM	UG/L	710.0	446.0	75.0	95.0	5.0 LT	5.0 LT
CHROMIUM	UG/L	250.0	520.0	510.0	520.0	26.0	10.0 LT
COPPER	UG/L	76.0	350.0	350.0	420.0	61.0	10.0 LT
LEAD	UG/L	64.0	140.0	140.0	200.0	330.0	50.0 LT
MERCURY	UG/L	.3 LT	.3 LT	.3 LT	.3 LT	.3 LT	.3 LT
NICKEL	UG/L	50.0 LT	550.0	540.0	610.0	50.0 LT	50.0 LT
SELENIUM	UG/L	25.0 LT	25.0 LT	25.0 LT	25.0 LT	25.0 LT	25.0 LT
SILVER	UG/L	.5 LT	1.4	1.4	2.0	2.0	.5 LT
THALLIUM	UG/L	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT
ZINC	UG/L	280.0	1650.0	1610.0	1980.0	280.0	10.0 LT
OTHERS							
CYANIDE	UG/L	20.0 LT	1300.0	2300.0	3200.0	20.0 LT	20.0 LT
NONCONVENTIONAL METALS							
ALUMINUM	UG/L	490.0	3210.0	3420.0	4760.0	4200.0	160.0
BARIUM	UG/L	36.0	66.0	69.0	89.0	160.0	10.0 LT
BORON	UG/L	550.0	270.0	220.0	240.0	27.0	20.0 LT
CALCIUM	UG/L	24000.0	13400.0	13600.0	13200.0	13100.0	2820.0

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POLLUTANTS NOT LISTED WERE NOT DETECTED

TABLE C-06

SEATTLE. WA. STORM EVENT ONE

POLLUTANT	UNITS	LAN WW BKGD 10914	LAN CSF 10915	LAN CSO 10916	LAN FIRST FLUSH 10917	LAN RUNOFF 10918	LAN PRECIP 10924
COBALT	UG/L	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT
IRON	UG/L	3490.0	6800.0	7060.0	9300.0	7390.0	280.0
MAGNESIUM	UG/L	8350.0	4430.0	4540.0	4660.0	2010.0	100.0
MANGANESE	UG/L	270.0	170.0	170.0	190.0	120.0	10.0 LT
MOLYBDENUM	UG/L	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT
SODIUM	UG/L	89000.0	44400.0	58600.0	51000.0	1450.0	2000.0 LT
TIN	UG/L	63.0	30.0 LT	30.0 LT	30.0 LT	30.0 LT	30.0 LT
TITANIUM	UG/L	50.0 LT	160.0	180.0	260.0	240.0	50.0 LT
VANADIUM	UG/L	5.0 LT	9.0	10.0	18.0	15.0	5.0 LT
YTTRIUM	UG/L	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT
VOLATILE ORGANICS							
TOLUENE	UG/L	29.0	82.0	127.0	86.0	ND	ND
BENZENE	UG/L	8.0	ND	ND	ND	ND	ND
ETHYLBENZENE	UG/L	8.0	ND	ND	ND	ND	ND
METHYLENE CHLORIDE	UG/L	24.0	94.0	120.0	210.0	ND	ND
TETRACHLOROETHENE	UG/L	24.0	3.7	ND	6.0	ND	ND
1,1,1-TRICHLOROETHANE	UG/L	ND	ND	8.0	7.0	ND	ND
TRANS-1,2-DICHLOROETHENE	UG/L	660.0	ND	ND	ND	ND	ND
TRICHLOROETHENE	UG/L	440.0	470.0	608.0	560.0	ND	ND
SEMI-VOLATILE BASE/NEUTRALS							
BIS(2-ETHYLHEXYL)PHTHALATE	UG/L	19.0	ND	ND	ND	ND	ND
SEMIVOLATILE ACID							
2,4-DICHLOROPHENOL	UG/L	17.0	ND	ND	ND	ND	ND
2,4-DIMETHYLPHENOL	UG/L	ND	19.0	ND	14.0	ND	ND
PHENOL	UG/L	ND	ND	16.0	16.0	ND	ND
PESTICIDE EXTRACTABLES							

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TABLE C-06

SEATTLE. WA. STORM EVENT ONE

POLLUTANT	UNITS	MICH WW BKGD 10919	MICH CSF 10920	MICH CSO 10921	MICH FIRST FLUSH 10922	MICH RUNOFF 10923
CONVENTIONAL/NONCONVENTIONAL						
BIOCHEMICAL OXYGEN DEMAND	MG/L	78.0	30.0	30.0 LT	30.0 LT	30.0 LT
CHEMICAL OXYGEN DEMAND	MG/L	231.0	161.0	87.0	153.0	161.0
TOTAL ORGANIC CARBON	MG/L	84.5	39.0	30.5	NS	NS
NON-PARTICULATE TOC	MG/L	NS	NS	NS	21.0	13.0
TOTAL SOLIDS	MG/L	337.0	187.0	163.0	191.0	232.0
TOTAL VOLATILE SOLIDS	MG/L	116.0	73.0	52.0	67.0	61.0
TOTAL VOL SUS SOLIDS	MG/L	71.0	35.0	26.0	45.0	44.0
TOTAL SUSPENDED SOLIDS	MG/L	89.0	92.0	77.0	118.0	169.0
TOTAL VOL DIS SOLIDS	MG/L	76.0	47.0	66.0	23.0	25.0
TOTAL DISSOLVED SOLIDS	MG/L	248.0	97.0	87.0	73.0	63.0
SETTLEABLE SOLIDS	ML/L	3.0	1.0	1.0 LT	1.0	1.0 LT
CHLORIDE	MG/L	21.0	3.0	1.0	3.0	3.0
AMMONIA NITROGEN	MG/L	4.2	1.1	1.1	.9	.2
TOTAL PHENOL	UG/L	37.5	37.5	150.0	450.0	7.5
OIL AND GREASE	MG/L	20.0	8.0	13.5	10.0	15.3
METALS						
ANTIMONY	UG/L	5.0 LT	5.0 LT	5.0 LT	5.0 LT	14.0
ARSENIC	UG/L	25.0 LT	25.0 LT	25.0 LT	25.0 LT	35.0
BERYLLIUM	UG/L	1.0 LT	1.0 LT	1.0 LT	1.0 LT	1.0 LT
CADMIUM	UG/L	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT
CHROMIUM	UG/L	50.0	10.0 LT	30.0	40.0	30.0
COPPER	UG/L	40.0	10.0 LT	40.0	50.0	120.0
LEAD	UG/L	50.0 LT	160.0	120.0	190.0	460.0
MERCURY	UG/L	.3 LT	.3 LT	.3 LT	.3 LT	.3 LT
NICKEL	UG/L	50.0 LT	50.0 LT	50.0 LT	50.0 LT	50.0 LT
SELENIUM	UG/L	25.0 LT	25.0 LT	25.0 LT	25.0 LT	25.0 LT
SILVER	UG/L	4.0	1.3	3.8	1.4	.5 LT
THALLIUM	UG/L	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT
ZINC	UG/L	140.0	190.0	160.0	220.0	390.0
OTHERS						
CYANIDE	UG/L	26.0	20.0 LT	20.0 LT	20.0 LT	20.0 LT
NONCONVENTIONAL METALS						
ALUMINUM	UG/L	950.0	3130.0	2130.0	380.0	5510.0
BARIUM	UG/L	25.0	40.0	30.0	50.0	110.0
BORON	UG/L	200.0	50.0	60.0	60.0	20.0
CALCIUM	UG/L	18400.0	9890.0	8540.0	9090.0	12000.0

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TABLE C-06
SEATTLE. WA. STORM EVENT ONE

POLLUTANT	UNITS	MICH WW BKGD 10919	MICH CSF 10920	MICH CSO 10921	MICH FIRST FLUSH 10922	MICH RUNOFF 10923
COBALT	UG/L	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT
IRON	UG/L	2710.0	4830.0	3460.0	5910.0	9980.0
MAGNESIUM	UG/L	6390.0	3350.0	2620.0	3010.0	2570.0
MANGANESE	UG/L	170.0	110.0	90.0	110.0	160.0
MOLYBDENUM	UG/L	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT
SODIUM	UG/L	30800.0	11000.0	6570.0	5780.0	2000.0 LT
TIN	UG/L	30.0 LT	30.0 LT	30.0 LT	30.0 LT	30.0 LT
TITANIUM	UG/L	50.0 LT	180.0	100.0	220.0	360.0
VANADIUM	UG/L	5.0 LT	5.0 LT	5.0 LT	5.0 LT	20.0
YTTRIUM	UG/L	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT
VOLATILE ORGANICS						
CHLOROFORM	UG/L	ND	9.0	ND	8.0	ND
TOLUENE	UG/L	13.0	ND	5.0	ND	ND
METHYLENE CHLORIDE	UG/L	295.0	42.0	41.0	37.0	350.0
TETRACHLOROETHENE	UG/L	ND	7.0	9.0	8.0	ND
1.1.1-TRICHLOROETHANE	UG/L	ND	13.0	16.0	13.0	ND
TRICHLOROETHENE	UG/L	280.0	96.0	120.0	100.0	ND
SEMI-VOLATILE BASE/NEUTRALS						
BIS(2-ETHYLHEXYL)PHTHALATE	UG/L	13.0	ND	32.0	ND	200.0
SEMIVOLATILE ACID						
2.4-DIMETHYLPHENOL	UG/L	38.0	ND	ND	ND	ND
PHENOL	UG/L	15.0	ND	ND	ND	ND
PESTICIDE EXTRACTABLES						

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TABLE C-07
SEATTLE, WA.   STORM EVENT TWO

POLLUTANT	UNITS	LAN WW BKGD 10925	LAN CSF 10926	LAN CSO 10927	LAN FIRST FLUSH 10928	LAN RUNOFF 10929	LAN PRECIP 10935
CONVENTIONAL/NONCONVENTIONAL							
BIOCHEMICAL OXYGEN DEMAND	MG/L	100.0 LT	75.0 LT	75.0 LT	75.0 LT	12.0 LT	12.0 LT
CHEMICAL OXYGEN DEMAND	MG/L	125.0	135.0	140.0	260.0	120.0	25.0 LT
TOTAL ORGANIC CARBON	MG/L	78.0	75.0	85.0	79.0	35.0	7.5
TOTAL SOLIDS	MG/L	314.0	433.0	440.0	458.0	184.0	16.0
TOTAL VOLATILE SOLIDS	MG/L	166.0	163.0	123.0	129.0	70.0	14.0
TOTAL VOL SUS SOLIDS	MG/L	52.0	80.0	44.0	55.0	28.0	4.0
TOTAL SUSPENDED SOLIDS	MG/L	83.0	151.0	81.0	98.0	102.0	4.0
TOTAL VOL DIS SOLIDS	MG/L	114.0	82.0	79.0	74.0	42.0	10.0
TOTAL DISSOLVED SOLIDS	MG/L	231.0	283.0	359.0	360.0	82.0	12.0
SETTLEABLE SOLIDS	ML/L	1.0 LT	2.9	1.4	1.0 LT	.4	1.0 LT
CHLORIDE	MG/L	49.0	120.0	147.0	146.0	2.0	1.0
AMMONIA NITROGEN	MG/L	1.8	1.2	1.7	2.0	1.0 LT	1.0 LT
TOTAL PHENOL	UG/L	57.0	67.0	17.0	10.0	7.5	10.0
OIL AND GREASE	MG/L	15.0	6.0	6.0	11.0	6.0	5.0 LT
METALS							
ANTIMONY	UG/L	5.0 LT	5.0 LT	5.0	5.0 LT	5.0	5.0 LT
ARSENIC	UG/L	22.0	20.0	18.0	19.0	20.0	6.0
BERYLLIUM	UG/L	1.0 LT	1.0 LT	1.0 LT	1.0 LT	2.0	1.0 LT
CADMIUM	UG/L	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT
CHROMIUM	UG/L	28.0	27.0	37.0	30.0	21.0	10.0 LT
COPPER	UG/L	150.0	300.0	250.0	180.0	100.0	10.0
LEAD	UG/L	140.0	250.0	220.0	210.0	330.0	50.0 LT
MERCURY	UG/L	.3 LT	.3 LT	.3 LT	.3 LT	.3 LT	.3 LT
NICKEL	UG/L	68.0	50.0 LT	60.0	57.0	50.0 LT	50.0 LT
SELENIUM	UG/L	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT
SILVER	UG/L	1.0 LT	1.0 LT	1.0 LT	1.0 LT	1.0 LT	1.0 LT
THALLIUM	UG/L	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT
ZINC	UG/L	315.0	360.0	360.0	320.0	340.0	45.0
OTHERS							
CYANIDE	UG/L	20.0 LT	20.0 LT	20.0 LT	20.0 LT	20.0 LT	20.0 LT
NONCONVENTIONAL METALS							
ALUMINUM	UG/L	2100.0	2810.0	2660.0	2250.0	3940.0	140.0
BARIUM	UG/L	54.0	62.0	61.0	55.0	100.0	10.0 LT
BORON	UG/L	69.0	72.0	44.0	68.0	20.0 LT	20.0 LT
CALCIUM	UG/L	17400.0	13800.0	14200.0	16300.0	15200.0	5250.0
COBALT	UG/L	5.0 LT	5.0 LT	5.0 LT	5.0	5.0 LT	5.0 LT

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TABLE C-07
SEATTLE. WA. STORM EVENT TWO

POLLUTANT	UNITS	LAN WW BKGD 10925	LAN CSF 10926	LAN CSO 10927	LAN FIRST FLUSH 10928	LAN RUNOFF 10929	LAN PRECIP 10935
IRON	UG/L	3790.0	4630.0	4740.0	4080.0	6000.0	170.0
MAGNESIUM	UG/L	3000.0	3000.0	2900.0	2890.0	1800.0	48.0
MANGANESE	UG/L	110.0	110.0	120.0	110.0	100.0	10.0 LT
MOLYBDENUM	UG/L	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT
SODIUM	UG/L	42500.0 LT	92900.0	107000.0	113000.0	2020.0	2000.0 LT
TIN	UG/L	30.0 LT	30.0 LT	30.0 LT	30.0 LT	30.0 LT	30.0 LT
TITANIUM	UG/L	90.0	110.0	120.0	100.0	200.0	5.0 LT
VANADIUM	UG/L	7.0	9.0	10.0	15.0	18.0	5.0 LT
YTTRIUM	UG/L	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT
VOLATILE ORGANICS							
METHYLENE CHLORIDE	UG/L	ND	ND	34.0	ND	ND	ND
TRICHLOROETHENE	UG/L	ND	13.0	ND	ND	ND	ND
SEMI-VOLATILE BASE/NEUTRALS							
DI-N-BUTYL PHTHALATE	UG/L	ND	ND	ND	ND	44.0	ND
SEMIVOLATILE ACID							
PESTICIDE EXTRACTABLES							

LT = LESS THAN
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POLLUTANTS NOT LISTED WERE NOT DETECTED

TABLE C-07
SEATTLE, WA. STORM EVENT TWO

POLLUTANT	UNITS	MICH WW BKGD 10930	MICH CSF 10931	MICH CSO 10932	MICH FIRST FLUSH 10933	MICH RUNOFF 10934	LAN PRECIP 10935
CONVENTIONAL/NONCONVENTIONAL							
BIOCHEMICAL OXYGEN DEMAND	MG/L	85.0	73.0	77.0	72.0	12.0	12.0 LT
CHEMICAL OXYGEN DEMAND	MG/L	250.0	88.0	130.0	250.0	130.0	25.0 LT
TOTAL ORGANIC CARBON	MG/L	100.0	81.0	77.0	77.0	52.0	7.5
TOTAL SOLIDS	MG/L	219.0	182.0	185.0	180.0	228.0	16.0
TOTAL VOLATILE SOLIDS	MG/L	134.0	125.0	110.0	105.0	85.0	14.0
TOTAL VOL SUS SOLIDS	MG/L	47.0	45.0	45.0	51.0	41.0	4.0
TOTAL SUSPENDED SOLIDS	MG/L	73.0	68.0	83.0	73.0	155.0	4.0
TOTAL VOL DIS SOLIDS	MG/L	87.0	80.0	64.0	54.0	44.0	10.0
TOTAL DISSOLVED SOLIDS	MG/L	146.0	114.0	102.0	107.0	73.0	12.0
SETTLEABLE SOLIDS	ML/L	1.0 LT	1.0 LT	2.6	1.0 LT	1.0 LT	1.0 LT
CHLORIDE	MG/L	8.0	7.0	7.0	8.0	4.0	1.0
AMMONIA NITROGEN	MG/L	1.9	1.5	1.3	1.6	1.0 LT	1.0 LT
TOTAL PHENOL	UG/L	48.0	69.0	75.0	77.0	16.0	10.0
OIL AND GREASE	MG/L	9.0	10.0	7.0	7.0	17.0	5.0 LT
METALS							
ANTIMONY	UG/L	5.0 LT	5.0	5.0 LT	5.0 LT	6.0	5.0 LT
ARSENIC	UG/L	16.0	12.0	10.0	12.0	24.0	6.0
BERYLLIUM	UG/L	1.0 LT	1.0 LT	1.0 LT	1.0 LT	1.0 LT	1.0 LT
CADMIUM	UG/L	5.0	7.0	7.0	7.0	5.0 LT	5.0 LT
CHROMIUM	UG/L	180.0	300.0	220.0	240.0	29.0	10.0 LT
COPPER	UG/L	66.0	60.0	63.0	57.0	180.0	10.0
LEAD	UG/L	180.0	210.0	200.0	180.0	490.0	50.0 LT
MERCURY	UG/L	.3 LT	.3 LT	.4	.3 LT	.3 LT	.3 LT
NICKEL	UG/L	50.0 LT	50.0 LT	50.0 LT	50.0 LT	50.0 LT	50.0 LT
SELENIUM	UG/L	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT
SILVER	UG/L	1.4	1.0 LT	1.1	1.0 LT	1.0 LT	1.0 LT
THALLIUM	UG/L	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT
ZINC	UG/L	240.0	220.0	220.0	200.0	440.0	45.0
OTHERS							
CYANIDE	UG/L	20.0 LT	60.0	20.0 LT	20.0 LT	20.0 LT	20.0 LT
NONCONVENTIONAL METALS							
ALUMINUM	UG/L	1470.0	1500.0	1870.0	1520.0	5820.0	140.0
BARIUM	UG/L	56.0	43.0	49.0	47.0	440.0	10.0 LT
BORON	UG/L	43.0	41.0	51.0	37.0	20.0 LT	20.0 LT
CALCIUM	UG/L	14100.0	13200.0	12000.0	13200.0	16200.0	5250.0
COBALT	UG/L	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0	5.0 LT

LT = LESS THAN
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POLLUTANTS NOT LISTED WERE NOT DETECTED

TABLE C-07

SEATTLE. WA. STORM EVENT TWO

POLLUTANT	UNITS	MICH WW BKGD 10930	MICH CSF 10931	MICH CSO 10932	MICH FIRST FLUSH 10933	MICH RUNOFF 10934	LAN PRECIP 10935
IRON	UG/L	2580.0	2610.0	2860.0	2400.0	9060.0	170.0
MAGNESIUM	UG/L	2190.0	2100.0	2030.0	2140.0	2710.0	48.0
MANGANESE	UG/L	76.0	79.0	73.0	72.0	150.0	10.0 LT
MOLYBDENUM	UG/L	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT
SODIUM	UG/L	6780.0	6410.0	5980.0	7490.0	2470.0	2000.0 LT
TIN	UG/L	30.0 LT	30.0 LT	30.0 LT	30.0 LT	30.0 LT	30.0 LT
TITANIUM	UG/L	62.0	68.0	82.0	64.0	310.0	5.0 LT
VANADIUM	UG/L	7.0	9.0	6.0	5.0 LT	22.0	5.0 LT
YTTRIUM	UG/L	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT
VOLATILE ORGANICS							
TOLUENE	UG/L	ND	27.0	19.0	27.0	ND	ND
METHYLENE CHLORIDE	UG/L	42.0	230.0	340.0	200.0	ND	ND
1.1.1-TRICHLOROETHANE	UG/L	ND	64.0	45.0	70.0	ND	ND
TRICHLOROETHENE	UG/L	ND	40.0	41.0	34.0	ND	ND
SEMI-VOLATILE BASE/NEUTRALS							
SEMIVOLATILE ACID							
PESTICIDE EXTRACTABLES							

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TABLE C-08
SEATTLE. WA. STORM EVENT THREE

POLLUTANT	UNITS	LAN WW BKGD 10936	LAN CSF 10937	LAN CSO 10938	LAN FIRST FLUSH 10939	LAN RUNOFF 10940	LAN PRECIP 10946
CONVENTIONAL/NONCONVENTIONAL							
BIOCHEMICAL OXYGEN DEMAND	MG/L	140.0	130.0	49.0	390.0	15.0 LT	15.0 LT
CHEMICAL OXYGEN DEMAND	MG/L	540.0	330.0	170.0	690.0	160.0	25.0 LT
TOTAL ORGANIC CARBON	MG/L	NS	NS	NS	NS	NS	7.5
NON-PARTICULATE TOC	MG/L	90.0	78.0	43.0	230.0	23.0	NS
TOTAL SOLIDS	MG/L	497.0	603.0	283.0	927.0	264.0	22.0
TOTAL VOLATILE SOLIDS	MG/L	246.0	314.0	138.0	321.0	156.0	20.0
TOTAL VOL SUS SOLIDS	MG/L	160.0	177.0	48.0	59.0	82.0	4.0 LT
TOTAL SUSPENDED SOLIDS	MG/L	306.0	287.0	139.0	161.0	215.0	7.0
TOTAL VOL DIS SOLIDS	MG/L	86.0	137.0	90.0	262.0	74.0	20.0
TOTAL DISSOLVED SOLIDS	MG/L	191.0	316.0	144.0	766.0	49.0	15.0
SETTLEABLE SOLIDS	ML/L	4.8	1.0 LT	1.0 LT	1.6	1.0 LT	1.0 LT
CHLORIDE	MG/L	48.0	280.0	68.0	630.0	4.8	3.2
AMMONIA NITROGEN	MG/L	3.0	3.0	2.4	6.1	1.0 LT	1.0 LT
TOTAL PHENOL	UG/L	32.0	23.0	25.0	38.0	20.0	14.0
OIL AND GREASE	MG/L	35.0	17.0	11.0	46.0	5.0	10.0 LT
METALS							
ANTIMONY	UG/L	9.0	5.0 LT	5.0	5.0 LT	5.0 LT	5.0 LT
ARSENIC	UG/L	22.0	330.0	10.0 LT	10.0 LT	18.0	10.0 LT
BERYLLIUM	UG/L	1.0 LT	1.0 LT	1.0 LT	1.0 LT	1.0 LT	1.0
CADMIUM	UG/L	15.0	6.0	5.0	5.0 LT	5.0	5.0 LT
CHROMIUM	UG/L	150.0	55.0	43.0	52.0	39.0	10.0 LT
COPPER	UG/L	2340.0	900.0	770.0	450.0	91.0	10.0 LT
LEAD	UG/L	820.0	390.0	390.0	260.0	410.0	50.0 LT
MERCURY	UG/L	3.2	.6	.4	.6	.4	.3 LT
NICKEL	UG/L	110.0	140.0	140.0	69.0	50.0 LT	50.0 LT
SELENIUM	UG/L	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT
SILVER	UG/L	3.1	.6	.6	.7	.5 LT	.5 LT
THALLIUM	UG/L	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT
ZINC	UG/L	1150.0	520.0	460.0	390.0	440.0	35.0
OTHERS							
CYANIDE	UG/L	34.0	64.0	45.0	120.0	20.0 LT	20.0 LT
NONCONVENTIONAL METALS							
ALUMINUM	UG/L	7940.0	4320.0	3860.0	2830.0	6310.0	79.0
BARIUM	UG/L	190.0	84.0	79.0	61.0	110.0	10.0 LT
BORON	UG/L	58.0	44.0	45.0	120.0	27.0	20.0 LT
CALCIUM	UG/L	15800.0	12400.0	10400.0	15900.0	10500.0	2080.0

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TABLE C-08
SEATTLE. WA. STORM EVENT THREE

POLLUTANT	UNITS	LAN WW BKGD 10936	LAN CSF 10937	LAN CSO 10938	LAN FIRST FLUSH 10939	LAN RUNOFF 10940	LAN PRECIP 10946
COBALT	UG/L	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT
IRON	UG/L	13500.0	7160.0	6450.0	5390.0	10400.0	150.0
MAGNESIUM	UG/L	4540.0	6320.0	2520.0	11300.0	2630.0	41.0
MANGANESE	UG/L	200.0	130.0	120.0	130.0	180.0	10.0 LT
MOLYBDENUM	UG/L	13.0	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT
SODIUM	UG/L	22200.0	60600.0	24800.0	139000.0	2170.0	2000.0 LT
TIN	UG/L	33.0	30.0 LT	30.0 LT	30.0 LT	30.0 LT	30.0 LT
TITANIUM	UG/L	460.0	260.0	230.0	160.0	360.0	50.0 LT
VANADIUM	UG/L	23.0	8.0	12.0	5.0 LT	17.0	5.0 LT
YTTRIUM	UG/L	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT
VOLATILE ORGANICS							
TETRACHLOROETHENE	UG/L	6.2	19.0	7.5	9.0	ND	2.0
SEMI-VOLATILE BASE/NEUTRALS							
PHENANTHRENE	UG/L	2.0	2.0	ND	1.0	ND	ND
1,4-DICHLOROBENZENE	UG/L	2.0	2.0	1.0	2.0	ND	ND
DI-N-OCTYL PHTHALATE	UG/L	2.0	ND	9.0	ND	ND	ND
NAPHTHALENE	UG/L	2.0	2.0	1.0	1.0	ND	ND
BIS(2-ETHYLHEXYL)PHTHALATE	UG/L	15.0	3.0	4.0	4.0	6.0	3.0
DI-N-BUTYL PHTHALATE	UG/L	2.0	6.0	ND	6.0	7.0	ND
SEMIVOLATILE ACID							
4-CHLORO-3-METHYLPHENOL	UG/L	26.0	66.0	37.0	14.0	ND	9.0
2,4-DIMETHYLPHENOL	UG/L	ND	7.0	ND	5.0	7.0	12.0
PHENOL	UG/L	5.0	6.0	6.0	4.0	4.0	7.0
PESTICIDE EXTRACTABLES							
PCB-1016	UG/L	3.3	1.3	2.6	ND	ND	ND

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TABLE C-08
SEATTLE. WA. STORM EVENT THREE

POLLUTANT	UNITS	MICH WW BKGD 10941	MICH CSF 10942	MICH CSO 10943	MICH FIRST FLUSH 10944	MICH RUNOFF 10945	LAN PRECIP 10946
CONVENTIONAL/NONCONVENTIONAL							
BIOCHEMICAL OXYGEN DEMAND	MG/L	69.0	41.0	36.0	59.0	15.0 LT	15.0 LT
CHEMICAL OXYGEN DEMAND	MG/L	220.0	110.0	110.0	140.0	190.0	25.0 LT
TOTAL ORGANIC CARBON	MG/L	NS	NS	NS	NS	NS	7.5
NON-PARTICULATE TOC	MG/L	34.0	25.0	27.0	34.0	22.0	NS
TOTAL SOLIDS	MG/L	284.0	147.0	145.0	251.0	113.0	22.0
TOTAL VOLATILE SOLIDS	MG/L	132.0	97.0	70.0	101.0	28.0	20.0
TOTAL VOL SUS SOLIDS	MG/L	74.0	33.0	37.0	75.0	15.0	4.0 LT
TOTAL SUSPENDED SOLIDS	MG/L	224.0	81.0	88.0	179.0	61.0	7.0
TOTAL VOL DIS SOLIDS	MG/L	58.0	64.0	33.0	26.0	13.0	20.0
TOTAL DISSOLVED SOLIDS	MG/L	60.0	66.0	57.0	72.0	52.0	15.0
SETTLEABLE SOLIDS	ML/L	3.2	1.0 LT	1.0 LT	2.3	1.0 LT	1.0 LT
CHLORIDE	MG/L	8.1	6.5	8.1	11.0	4.8	3.2
AMMONIA NITROGEN	MG/L	2.0	2.5	2.8	3.3	1.0 LT	1.0 LT
TOTAL PHENOL	UG/L	16.0	16.0	20.0	22.0	28.0	14.0
OIL AND GREASE	MG/L	10.0 LT	25.0	5.0 LT	12.0	9.4	10.0 LT
METALS							
ANTIMONY	UG/L	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT
ARSENIC	UG/L	10.0 LT	16.0	18.0	16.0	10.0 LT	10.0 LT
BERYLLIUM	UG/L	1.0 LT	1.0 LT	1.0 LT	1.0 LT	3.0	1.0
CADMIUM	UG/L	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT
CHROMIUM	UG/L	34.0	94.0	81.0	96.0	17.0	10.0 LT
COPPER	UG/L	31.0	59.0	61.0	79.0	98.0	10.0 LT
LEAD	UG/L	53.0	220.0	220.0	280.0	200.0	50.0 LT
MERCURY	UG/L	24.0	1.0	1.0	1.6	.3	.3 LT
NICKEL	UG/L	50.0 LT	50.0 LT	50.0 LT	50.0 LT	50.0 LT	50.0 LT
SELENIUM	UG/L	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT
SILVER	UG/L	.8	2.6	3.3	3.2	.5 LT	.5 LT
THALLIUM	UG/L	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT
ZINC	UG/L	120.0	250.0	230.0	320.0	250.0	35.0
OTHERS							
CYANIDE	UG/L	20.0 LT	20.0 LT	20.0 LT	20.0 LT	20.0 LT	20.0 LT
NONCONVENTIONAL METALS							
ALUMINUM	UG/L	910.0	2770.0	2750.0	3130.0	2980.0	79.0
BARIUM	UG/L	25.0	53.0	53.0	71.0	93.0	10.0 LT
BORON	UG/L	25.0	37.0	51.0	64.0	32.0	20.0 LT
CALCIUM	UG/L	9200.0	8520.0	8270.0	9680.0	8530.0	2080.0

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TABLE C-08
SEATTLE, WA. STORM EVENT THREE

POLLUTANT	UNITS	MICH WW BKGD 10941	MICH CSF 10942	MICH CSO 10943	MICH FIRST FLUSH 10944	MICH RUNOFF 10945	LAN PRECIP 10946
COBALT	UG/L	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT
IRON	UG/L	1560.0	4200.0	4310.0	4870.0	4840.0	150.0
MAGNESIUM	UG/L	1340.0	1780.0	1770.0	1990.0	1410.0	41.0
MANGANESE	UG/L	58.0	84.0	83.0	92.0	78.0	10.0 LT
MOLYBDENUM	UG/L	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT
SODIUM	UG/L	4170.0	4080.0	3330.0	4600.0	2000.0 LT	2000.0 LT
TIN	UG/L	30.0 LT	30.0 LT	30.0 LT	30.0 LT	30.0 LT	30.0 LT
TITANIUM	UG/L	72.0	180.0	160.0	210.0	190.0	50.0 LT
VANADIUM	UG/L	5.0 LT	7.0	5.0	7.0	5.0 LT	5.0 LT
YTTRIUM	UG/L	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT
VOLATILE ORGANICS							
TETRACHLOROETHENE	UG/L	11.0	44.0	48.0	26.0	2.0	2.0
SEMI-VOLATILE BASE/NEUTRALS							
1,4-DICHLOROBENZENE	UG/L	2.0	ND	ND	ND	ND	ND
DI-N-OCTYL PHTHALATE	UG/L	ND	ND	ND	ND	4.0	ND
NAPHTHALENE	UG/L	ND	ND	ND	1.0	ND	ND
BIS(2-ETHYLHEXYL)PHTHALATE	UG/L	7.0	5.0	11.0	5.0	7.0	3.0
DI-N-BUTYL PHTHALATE	UG/L	3.0	4.0	1.0	1.0	1.0	ND
SEMIVOLATILE ACID							
4-CHLORO-3-METHYLPHENOL	UG/L	5.0	ND	9.0	6.0	2.0	9.0
2,4-DIMETHYLPHENOL	UG/L	ND	5.0	5.0	5.0	6.0	12.0
PHENOL	UG/L	ND	ND	5.0	6.0	15.0	7.0
PESTICIDE EXTRACTABLES							

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TABLE C-09

ST.LOUIS. MO DRY WEATHER COMPOSITE

POLLUTANT	UNITS	BRANCH DW BKGD 11084	PRAIR DW BKGD 11085	BRANCH TAP WATER 11086
CONVENTIONAL/NONCONVENTIONAL				
BIOCHEMICAL OXYGEN DEMAND	MG/L	54.0	200.0	5.0 LT
CHEMICAL OXYGEN DEMAND	MG/L	550.0	385.0	25.0 LT
TOTAL ORGANIC CARBON	MG/L	63.0	NS	14.5
NON-PARTICULATE TOC	MG/L	NS	121.0	NS
TOTAL SOLIDS	MG/L	726.0	668.0	322.0
TOTAL VOLATILE SOLIDS	MG/L	112.0	153.0	26.0
TOTAL VOL SUS SOLIDS	MG/L	42.0	49.0	4.0 LT
TOTAL SUSPENDED SOLIDS	MG/L	70.0	118.0	6.0
TOTAL VOL DIS SOLIDS	MG/L	70.0	104.0	26.0
TOTAL DISSOLVED SOLIDS	MG/L	656.0	550.0	316.0
SETTLEABLE SOLIDS	ML/L	1.0 LT	1.0 LT	1.0 LT
CHLORIDE	MG/L	124.0	47.0	21.0
AMMONIA NITROGEN	MG/L	3.7	4.5	1.0 LT
TOTAL PHENOL	UG/L	48.0	2460.0	5.0 LT
OIL AND GREASE	MG/L	15.0	11.0	5.0 LT
METALS				
ANTIMONY	UG/L	5.0 LT	5.0 LT	5.0 LT
ARSENIC	UG/L	5.0 LT	5.0 LT	5.0 LT
BERYLLIUM	UG/L	1.0 LT	1.0 LT	1.0 LT
CADMIUM	UG/L	5.0 LT	5.0 LT	5.0 LT
CHROMIUM	UG/L	24.0	86.0	10.0 LT
COPPER	UG/L	20.0 LT	20.0 LT	20.0 LT
LEAD	UG/L	50.0 LT	50.0 LT	50.0 LT
MERCURY	UG/L	.3 LT	.6	.3 LT
NICKEL	UG/L	50.0 LT	120.0	50.0 LT
SELENIUM	UG/L	5.0	6.0	5.0 LT
SILVER	UG/L	1.0 LT	1.0 LT	1.0 LT
THALLIUM	UG/L	10.0 LT	10.0 LT	10.0 LT
ZINC	UG/L	220.0	44.0	20.0 LT
OTHERS				
CYANIDE	UG/L	20.0 LT	125.0	20.0 LT
NONCONVENTIONAL METALS				
ALUMINUM	UG/L	640.0	2520.0	40.0 LT
BARIUM	UG/L	71.0	89.0	46.0
BORON	UG/L	120.0	200.0	20.0 LT
CALCIUM	UG/L	58400.0	57300.0	23000.0

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POLLUTANTS NOT LISTED WERE NOT DETECTED

TABLE C-09

ST.LOUIS. MO DRY WEATHER COMPOSITE

POLLUTANT	UNITS	BRANCH DW BKGD 11084	PRAIR DW BKGD 11085	BRANCH TAP WATER 11086
COBALT	UG/L	5.0 LT	5.0 LT	5.0 LT
IRON	UG/L	1650.0	3480.0	50.0
MAGNESIUM	UG/L	18400.0	21800.0	14700.0
MANGANESE	UG/L	170.0	270.0	10.0 LT
MOLYBDENUM	UG/L	10.0 LT	10.0 LT	10.0 LT
SODIUM	UG/L	138000.0	77300.0	41500.0
TIN	UG/L	30.0 LT	110.0	30.0 LT
TITANIUM	UG/L	20.0 LT	40.0	20.0 LT
VANADIUM	UG/L	5.0 LT	9.0	5.0 LT
YTTRIUM	UG/L	5.0 LT	5.0 LT	5.0 LT
VOLATILE ORGANICS___________				
CHLOROFORM	UG/L	6.7	ND	24.0
TOLUENE	UG/L	7.9	245.0	ND
ETHYLBENZENE	UG/L	ND	311.0	ND
METHYLENE CHLORIDE	UG/L	44.0	172.0	31.0
TETRACHLOROETHENE	UG/L	1.8	ND	ND
1.1.2.2-TETRACHLOROETHANE	UG/L	ND	5.5	ND
TRANS-1.2-DICHLOROETHENE	UG/L	2.8	ND	ND
TRICHLOROETHENE	UG/L	3.0	ND	ND
SEMIVOLATILE ORGANICS_______				
SEMI-VOLATILE BASE/NEUTRALS_				
DIETHYLPHTHALATE	UG/L	ND	3.8	ND
NAPHTHALENE	UG/L	ND	140.0	ND
BIS(2-ETHYLHEXYL)PHTHALATE	UG/L	ND	48.0	ND
DI-N-BUTYL PHTHALATE	UG/L	ND	20.0	ND
SEMIVOLATILE ACID___________				
2.4-DIMETHYLPHENOL	UG/L	ND	1392.0	ND
PHENOL	UG/L	ND	1236.0	ND
PESTICIDE EXTRACTABLES______				

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TABLE C-10

ST.LOUIS. MO   STORM EVENT ONE

POLLUTANT	UNITS	BRANCH WW BKGD 11087	BRANCH CSF 11088	BRANCH CSO 11089	BRANCH FIRST FLUSH 11090	BRANCH RUNOFF 11091	BRANCH PRECIP 11097
CONVENTIONAL/NONCONVENTIONAL							
BIOCHEMICAL OXYGEN DEMAND	MG/L	99.0	43.0	49.0	82.0	15.0	50.0 LT
CHEMICAL OXYGEN DEMAND	MG/L	210.0	170.0	250.0	330.0	64.0	25.0 LT
TOTAL ORGANIC CARBON	MG/L	NS	NS	NS	NS	NS	7.5
NON-PARTICULATE TOC	MG/L	55.0	24.0	22.0	37.0	30.0	NS
TOTAL SOLIDS	MG/L	945.0	579.0	620.0	314.0	788.0	77.0
TOTAL VOLATILE SOLIDS	MG/L	166.0	182.0	135.0	368.0	151.0	35.0
TOTAL VOL SUS SOLIDS	MG/L	68.0	80.0	96.0	92.0	14.0	19.0
TOTAL SUSPENDED SOLIDS	MG/L	86.0	362.0	435.0	47.0	179.0	53.0
TOTAL VOL DIS SOLIDS	MG/L	98.0	102.0	39.0	276.0	137.0	16.0
TOTAL DISSOLVED SOLIDS	MG/L	859.0	217.0	185.0	267.0	609.0	24.0
SETTLEABLE SOLIDS	ML/L	1.5	1.9	2.1	3.1	1.0 LT	1.0 LT
CHLORIDE	MG/L	670.0	71.0	71.0	140.0	4.8	3.2
AMMONIA NITROGEN	MG/L	1.0 LT	1.3	1.7	2.4	1.0 LT	1.0 LT
TOTAL PHENOL	UG/L	23.0	12.0	7.9	13.0	12.0	8.7
OIL AND GREASE	MG/L	21.0	20.0	29.0	27.0	10.0 LT	10.0 LT
METALS							
ANTIMONY	UG/L	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT
ARSENIC	UG/L	10.0 LT	14.0	16.0	10.0 LT	10.0 LT	10.0 LT
BERYLLIUM	UG/L	1.0 LT	1.0 LT	1.0 LT	1.0 LT	1.0 LT	1.0 LT
CADMIUM	UG/L	7.0	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT
CHROMIUM	UG/L	35.0	48.0	32.0	100.0	10.0	10.0 LT
COPPER	UG/L	23.0	94.0	100.0	160.0	37.0	10.0 LT
LEAD	UG/L	50.0 LT	360.0	420.0	470.0	360.0	50.0 LT
MERCURY	UG/L	.3	.4	.4	.7	.3 LT	.3 LT
NICKEL	UG/L	50.0 LT	50.0 LT	50.0 LT	50.0 LT	50.0 LT	50.0 LT
SELENIUM	UG/L	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT
SILVER	UG/L	.5 LT	.5 LT	.5 LT	.7	.5 LT	.5 LT
THALLIUM	UG/L	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT
ZINC	UG/L	720.0	420.0	450.0	630.0	230.0	110.0
OTHERS							
CYANIDE	UG/L	25.0	20.0 LT	20.0 LT	23.0	20.0 LT	20.0 LT
NONCONVENTIONAL METALS							
ALUMINUM	UG/L	690.0	8930.0	9830.0	8730.0	1520.0	40.0 LT
BARIUM	UG/L	52.0	180.0	210.0	220.0	48.0	10.0 LT
BORON	UG/L	210.0	82.0	77.0	75.0	40.0	20.0 LT
CALCIUM	UG/L	43400.0	26800.0	27000.0	34800.0	19600.0	1770.0

LT = LESS THAN
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POLLUTANTS NOT LISTED WERE NOT DETECTED

TABLE C-10
ST.LOUIS, MO STORM EVENT ONE

POLLUTANT	UNITS	BRANCH WW BKGD 11087	BRANCH CSF 11088	BRANCH CSO 11089	BRANCH FIRST FLUSH 11090	BRANCH RUNOFF 11091	BRANCH PRECIP 11097
COBALT	UG/L	5.0 LT	5.0 LT	5.0 LT	7.0	5.0 LT	5.0 LT
IRON	UG/L	940.0	12900.0	14400.0	11900.0	3330.0	37.0
MAGNESIUM	UG/L	22000.0	6620.0	6130.0	8970.0	2360.0	62.0
MANGANESE	UG/L	120.0	340.0	380.0	320.0	130.0	10.0 LT
MOLYBDENUM	UG/L	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT
SODIUM	UG/L	210000.0	32300.0	26900.0	39500.0	2280.0	2000.0 LT
TIN	UG/L	30.0 LT	30.0 LT	30.0 LT	30.0 LT	30.0 LT	30.0 LT
TITANIUM	UG/L	50.0 LT	99.0	120.0	100.0	50.0 LT	50.0 LT
VANADIUM	UG/L	5.0 LT	19.0	22.0	20.0	5.0 LT	5.0 LT
YTTRIUM	UG/L	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT
VOLATILE ORGANICS							
CHLOROFORM	UG/L	ND	ND	ND	4.7	ND	ND
TOLUENE	UG/L	12.4	13.0	9.2	9.7	ND	5.3
BENZENE	UG/L	2.5	ND	1.7	ND	ND	ND
ETHYLBENZENE	UG/L	8.5	ND	3.4	3.2	2.2	ND
METHYLENE CHLORIDE	UG/L	7.8	32.0	39.0	8.2	8.2	11.2
TETRACHLOROETHENE	UG/L	3.9	ND	ND	ND	ND	ND
1,1,1-TRICHLOROETHANE	UG/L	ND	58.0	60.0	40.0	ND	ND
TRANS-1,2-DICHLOROETHENE	UG/L	4.4	ND	ND	ND	ND	ND
TRICHLOROETHENE	UG/L	5.1	ND	4.0	ND	ND	ND
SEMIVOLATILE ORGANICS							
SEMI-VOLATILE BASE/NEUTRALS							
BENZO(K)FLUORANTHENE	UG/L	ND	ND	4.0	ND	ND	ND
DIMETHYLPHTHALATE	UG/L	28.0	ND	ND	ND	ND	ND
FLUORANTHENE	UG/L	ND	ND	4.0	ND	ND	ND
NAPHTHALENE	UG/L	4.6	ND	ND	ND	ND	ND
BIS(2-ETHYLHEXYL)PHTHALATE	UG/L	28.0	ND	20.0	75.0	14.0	13.0
DI-N-BUTYL PHTHALATE	UG/L	4.7	ND	ND	ND	ND	ND
SEMIVOLATILE ACID							
PHENOL	UG/L	ND	ND	ND	ND	ND	16.0
PESTICIDE EXTRACTABLES							

LT = LESS THAN
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TABLE C-10

ST.LOUIS. MO STORM EVENT ONE

POLLUTANT	UNITS	PRAIR WW BKGD 11092	PRAIR CSF 11093	PRAIR CSO 11094	PRAIR FIRST FLUSH 11095	PRAIR RUNOFF 11096	BRANCH PRECIP 11097
CONVENTIONAL/NONCONVENTIONAL							
BIOCHEMICAL OXYGEN DEMAND	MG/L	100.0	81.0	85.0	150.0	15.0 LT	50.0 LT
CHEMICAL OXYGEN DEMAND	MG/L	230.0	350.0	270.0	340.0	47.0	25.0 LT
TOTAL ORGANIC CARBON	MG/L	NS	NS	NS	NS	NS	7.5
NON-PARTICULATE TOC	MG/L	49.0	40.0	36.0	48.0	21.0	NS
TOTAL SOLIDS	MG/L	472.0	1009.0	568.0	1002.0	312.0	77.0
TOTAL VOLATILE SOLIDS	MG/L	394.0	141.0	419.0	270.0	107.0	35.0
TOTAL VOL SUS SOLIDS	MG/L	55.0	116.0	344.0	158.0	35.0	19.0
TOTAL SUSPENDED SOLIDS	MG/L	101.0	797.0	444.0	718.0	176.0	53.0
TOTAL VOL DIS SOLIDS	MG/L	339.0	25.0	75.0	112.0	72.0	16.0
TOTAL DISSOLVED SOLIDS	MG/L	371.0	212.0	124.0	284.0	136.0	24.0
SETTLEABLE SOLIDS	ML/L	1.4	2.2	1.8	3.6	1.0 LT	1.0 LT
CHLORIDE	MG/L	180.0	58.0	29.0	92.0	53.0	3.2
AMMONIA NITROGEN	MG/L	1.0 LT	2.7	1.5	4.0	1.0 LT	1.0 LT
TOTAL PHENOL	UG/L	7400.0	2000.0	1700.0	2000.0	5.0 LT	8.7
OIL AND GREASE	MG/L	20.0	14.0	10.0 LT	10.0 LT	10.0 LT	10.0 LT
METALS							
ANTIMONY	UG/L	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT
ARSENIC	UG/L	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT
BERYLLIUM	UG/L	1.0 LT	1.0 LT	1.0 LT	1.0 LT	1.0 LT	1.0 LT
CADMIUM	UG/L	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT
CHROMIUM	UG/L	120.0	79.0	60.0	140.0	17.0	10.0 LT
COPPER	UG/L	310.0	170.0	140.0	310.0	44.0	10.0 LT
LEAD	UG/L	76.0	370.0	430.0	560.0	220.0	50.0 LT
MERCURY	UG/L	.3	.6	.6	.3 LT	.3 LT	.3 LT
NICKEL	UG/L	56.0	92.0	64.0	160.0	50.0 LT	50.0 LT
SELENIUM	UG/L	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT
SILVER	UG/L	.5 LT	.5 LT	.5 LT	.5 LT	.5 LT	.5 LT
THALLIUM	UG/L	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT
ZINC	UG/L	91.0	450.0	470.0	640.0	290.0	110.0
OTHERS							
CYANIDE	UG/L	510.0	34.0	20.0 LT	20.0 LT	20.0 LT	20.0 LT
NONCONVENTIONAL METALS							
ALUMINUM	UG/L	1530.0	7600.0	9320.0	13800.0	2980.0	40.0 LT
BARIUM	UG/L	59.0	180.0	210.0	320.0	74.0	10.0 LT
BORON	UG/L	300.0	130.0	84.0	180.0	40.0	20.0 LT
CALCIUM	UG/L	47900.0	40900.0	35700.0	54700.0	40300.0	1770.0

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TABLE C-10

ST.LOUIS, MO STORM EVENT ONE

POLLUTANT	UNITS	PRAIR WW BKGD 11092	PRAIR CSF 11093	PRAIR CSO 11094	PRAIR FIRST FLUSH 11095	PRAIR RUNOFF 11096	BRANCH PRECIP 11097
COBALT	UG/L	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT
IRON	UG/L	1250.0	11700.0	13800.0	20100.0	4890.0	37.0
MAGNESIUM	UG/L	22100.0	9790.0	6800.0	15400.0	3920.0	62.0
MANGANESE	UG/L	190.0	360.0	350.0	540.0	160.0	10.0 LT
MOLYBDENUM	UG/L	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT
SODIUM	UG/L	94300.0	22000.0	10300.0	34800.0	12900.0	2000.0 LT
TIN	UG/L	420.0	120.0	30.0 LT	200.0	30.0 LT	30.0 LT
TITANIUM	UG/L	50.0 LT	91.0	110.0	160.0	50.0 LT	50.0 LT
VANADIUM	UG/L	5.0 LT	15.0	23.0	27.0	5.0	5.0 LT
YTTRIUM	UG/L	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT
VOLATILE ORGANICS							
CHLOROFORM	UG/L	42.0	12.5	117.0	22.0	ND	ND
TOLUENE	UG/L	605.0	393.0	293.0	296.0	6.0	5.3
ETHYLBENZENE	UG/L	344.0	63.0	59.0	61.0	ND	ND
METHYLENE CHLORIDE	UG/L	1499.0	21.0	30.0	26.0	9.3	11.2
1,1,1-TRICHLOROETHANE	UG/L	ND	3.2	3.2	5.0	ND	ND
SEMI-VOLATILE BASE/NEUTRALS							
ACENAPHTHENE	UG/L	88.0	ND	ND	ND	ND	ND
BENZO(K)FLUORANTHENE	UG/L	ND	ND	ND	ND	12.0	ND
NAPHTHALENE	UG/L	4.2	12.5	5.0	6.5	ND	ND
BIS(2-ETHYLHEXYL)PHTHALATE	UG/L	54.0	32.0	38.0	48.0	11.0	13.0
DI-N-BUTYL PHTHALATE	UG/L	6.7	5.1	ND	5.1	ND	ND
SEMIVOLATILE ACID							
2,4-DIMETHYLPHENOL	UG/L	612.0	181.0	125.0	183.0	ND	ND
PHENOL	UG/L	1652.0	708.0	103.0	404.0	ND	16.0
PESTICIDE EXTRACTABLES							

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TABLE C-11

ST.LOUIS, MO STORM EVENT TWO

POLLUTANT	UNITS	BRANCH WW BKGD 11098	BRANCH CSF 11099	BRANCH CSO 11100	BRANCH FIRST FLUSH 11101	BRANCH RUNOFF 11102	BRANCH PRECIP 11108
CONVENTIONAL/NONCONVENTIONAL							
BIOCHEMICAL OXYGEN DEMAND	MG/L	90.0	76.0	32.0	76.0	28.0	15.0 LT
CHEMICAL OXYGEN DEMAND	MG/L	220.0	290.0	140.0	250.0	95.0	64.0
TOTAL ORGANIC CARBON	MG/L	NS	NS	NS	NS	NS	8.0
NON-PARTICULATE TOC	MG/L	56.0	38.0	24.0	42.0	40.0	NS
TOTAL SOLIDS	MG/L	1180.0	789.0	266.0	538.0	198.0	12.0
TOTAL VOLATILE SOLIDS	MG/L	151.0	206.0	87.0	98.0	68.0	22.0
TOTAL VOL SUS SOLIDS	MG/L	45.0	145.0	30.0	67.0	34.0	22.0
TOTAL SUSPENDED SOLIDS	MG/L	65.0	474.0	96.0	181.0	99.0	4.0 LT
TOTAL VOL DIS SOLIDS	MG/L	106.0	61.0	57.0	31.0	34.0	4.0 LT
TOTAL DISSOLVED SOLIDS	MG/L	1115.0	315.0	170.0	357.0	99.0	10.0
SETTLEABLE SOLIDS	ML/L	1.4	9.1	1.0 LT	2.3	1.0 LT	1.0 LT
CHLORIDE	MG/L	330.0	59.0	2.3	47.0	3.8	2.3
AMMONIA NITROGEN	MG/L	7.0	3.0	2.5	3.3	1.0 LT	1.0 LT
TOTAL PHENOL	UG/L	25.0	16.0	7.0	12.0	10.0	5.0 LT
OIL AND GREASE	MG/L	18.0	33.0	18.0	34.0	9.0	10.0 LT
METALS							
ANTIMONY	UG/L	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT
ARSENIC	UG/L	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT
BERYLLIUM	UG/L	1.0 LT	1.0 LT	1.0 LT	1.0 LT	1.0 LT	1.0 LT
CADMIUM	UG/L	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT
CHROMIUM	UG/L	23.0	25.0	10.0	22.0	10.0 LT	10.0 LT
COPPER	UG/L	16.0	90.0	39.0	76.0	31.0	10.0 LT
LEAD	UG/L	50.0 LT	240.0	98.0	180.0	350.0	52.0 LT
MERCURY	UG/L	.3	.6	.3	.5	.5	.3 LT
NICKEL	UG/L	50.0 LT	50.0 LT	50.0 LT	50.0 LT	50.0 LT	50.0 LT
SELENIUM	UG/L	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT
SILVER	UG/L	.7	.8	.5	.5 LT	.5 LT	.5 LT
THALLIUM	UG/L	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT
ZINC	UG/L	300.0	350.0	160.0	310.0	270.0	120.0
OTHERS							
CYANIDE	UG/L	20.0 LT	20.0 LT	20.0 LT	20.0 LT	20.0 LT	20.0 LT
NONCONVENTIONAL METALS							
ALUMINUM	UG/L	1250.0	5420.0	3020.0	3920.0	1780.0	56.0
BARIUM	UG/L	60.0	160.0	59.0	140.0	61.0	10.0 LT
BORON	UG/L	420.0	100.0	48.0	85.0	72.0	20.0 LT
CALCIUM	UG/L	69800.0	31400.0	18400.0	32400.0	17500.0	1260.0

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TABLE C-11

ST. LOUIS, MO STORM EVENT TWO

POLLUTANT	UNITS	BRANCH WW BKGD 11098	BRANCH CSF 11099	BRANCH CSO 11100	BRANCH FIRST FLUSH 11101	BRANCH RUNOFF 11102	BRANCH PRECIP 11108
COBALT	UG/L	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT
IRON	UG/L	1740.0	9720.0	4560.0	8050.0	3580.0	88.0
MAGNESIUM	UG/L	18400.0	8430.0	3860.0	8710.0	2220.0	110.0
MANGANESE	UG/L	260.0	230.0	140.0	210.0	160.0	10.0 LT
MOLYBDENUM	UG/L	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT
SODIUM	UG/L	289000.0	55400.0	11600.0	65500.0	2060.0	2000.0 LT
TIN	UG/L	30.0 LT	30.0 LT	30.0 LT	30.0 LT	30.0 LT	30.0 LT
TITANIUM	UG/L	20.0 LT	79.0	39.0	68.0	27.0	20.0 LT
VANADIUM	UG/L	51.0	29.0	56.0	36.0	20.0	5.0 LT
YTTRIUM	UG/L	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT
VOLATILE ORGANICS							
CHLOROFORM	UG/L	13.0	5.8	4.9	6.4	3.3	ND
TOLUENE	UG/L	8.8	8.2	4.6	12.4	2.3	9.9
CHLOROBENZENE	UG/L	2.1	ND	1.9	ND	2.0	ND
ETHYLBENZENE	UG/L	4.5	ND	2.4	1.4	2.7	2.3
METHYLENE CHLORIDE	UG/L	8.2	7.5	10.3	11.2	9.3	11.9
TETRACHLOROETHENE	UG/L	ND	ND	3.7	2.1	ND	5.9
1,1,1-TRICHLOROETHANE	UG/L	ND	4.3	6.3	5.0	ND	ND
TRANS-1,2-DICHLOROETHENE	UG/L	4.1	ND	ND	ND	ND	ND
TRICHLOROETHENE	UG/L	3.5	ND	1.8	1.5	ND	ND
SEMI-VOLATILE BASE/NEUTRALS							
DIETHYLPHTHALATE	UG/L	4.2	ND	ND	ND	ND	ND
PYRENE	UG/L	ND	3.2	ND	ND	ND	ND
NAPHTHALENE	UG/L	ND	3.1	ND	3.3	ND	ND
BIS(2-ETHYLHEXYL)PHTHALATE	UG/L	19.0	25.0	11.6	18.0	19.0	ND
DI-N-BUTYL PHTHALATE	UG/L	3.1	4.6	4.0	3.8	7.0	ND
SEMIVOLATILE ACID							
PESTICIDE EXTRACTABLES							

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TABLE C-11
ST.LOUIS, MO STORM EVENT TWO

POLLUTANT	UNITS	PRAIR WW BKGD 11103	PRAIR CSF 11104	PRAIR CSO 11105	PRAIR FIRST FLUSH 11106	PRAIR RUNOFF 11107	BRANCH PRECIP 11108
CONVENTIONAL/NONCONVENTIONAL							
BIOCHEMICAL OXYGEN DEMAND	MG/L	190.0	34.0	46.0	67.0	15.0 LT	15.0 LT
CHEMICAL OXYGEN DEMAND	MG/L	370.0	140.0	170.0	180.0	25.0 LT	64.0
TOTAL ORGANIC CARBON	MG/L	NS	NS	NS	NS	19.0	8.0
NON-PARTICULATE TOC	MG/L	120.0	27.0	29.0	38.0	NS	NS
TOTAL SOLIDS	MG/L	766.0	181.0	207.0	295.0	105.0	12.0
TOTAL VOLATILE SOLIDS	MG/L	166.0	92.0	109.0	69.0	40.0	22.0
TOTAL VOL SUS SOLIDS	MG/L	64.0	49.0	42.0	44.0	12.0	22.0
TOTAL SUSPENDED SOLIDS	MG/L	102.0	43.0	125.0	129.0	47.0	4.0 LT
TOTAL VOL DIS SOLIDS	MG/L	102.0	43.0	67.0	25.0	28.0	4.0 LT
TOTAL DISSOLVED SOLIDS	MG/L	664.0	138.0	82.0	166.0	58.0	10.0
SETTLEABLE SOLIDS	ML/L	2.4	1.0 LT	1.1	1.1	1.0 LT	1.0 LT
CHLORIDE	MG/L	53.0	8.3	6.3	11.0	3.8	2.3
AMMONIA NITROGEN	MG/L	6.0	1.4	2.0	4.1	1.0 LT	1.0 LT
TOTAL PHENOL	UG/L	16500.0	780.0	830.0	1630.0	7.3	5.0 LT
OIL AND GREASE	MG/L	16.0	21.0	18.0	27.0	5.0 LT	10.0 LT
METALS							
ANTIMONY	UG/L	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT
ARSENIC	UG/L	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT
BERYLLIUM	UG/L	1.0 LT	1.0 LT	1.0 LT	1.0 LT	1.0 LT	1.0 LT
CADMIUM	UG/L	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT
CHROMIUM	UG/L	35.0	18.0	24.0	40.0	10.0 LT	10.0 LT
COPPER	UG/L	110.0	38.0	55.0	61.0	17.0	10.0 LT
LEAD	UG/L	50.0 LT	78.0	160.0	160.0	52.0	52.0 LT
MERCURY	UG/L	1.0	.4	.4	.4	.3 LT	.3 LT
NICKEL	UG/L	130.0	50.0 LT	50.0 LT	50.0 LT	50.0 LT	50.0 LT
SELENIUM	UG/L	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT
SILVER	UG/L	.5 LT	.5 LT	.5 LT	.5 LT	.5 LT	.5 LT
THALLIUM	UG/L	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT
ZINC	UG/L	52.0	160.0	210.0	250.0	130.0	120.0
OTHERS							
CYANIDE	UG/L	140.0	20.0 LT	20.0 LT	20.0 LT	20.0 LT	20.0 LT
NONCONVENTIONAL METALS							
ALUMINUM	UG/L	1100.0	1870.0	3620.0	3610.0	830.0	56.0
BARIUM	UG/L	40.0	37.0	71.0	76.0	23.0	10.0 LT
BORON	UG/L	920.0	68.0	79.0	81.0	20.0 LT	20.0 LT
CALCIUM	UG/L	49300.0	17800.0	20700.0	24300.0	19600.0	1260.0

LT = LESS THAN
GT = GREATER THAN
ND = NOT DETECTED
NS = NOT SAMPLED
PULLUTANTS NOT LISTED WERE NOT DETECTED

TABLE C-11
ST. LOUIS, MO STORM EVENT TWO

POLLUTANT	UNITS	PRAIR WW BKGD 11103	PRAIR CSF 11104	PRAIR CSO 11105	PRAIR FIRST FLUSH 11106	PRAIR RUNOFF 11107	BRANCH PRECIP 11108
COBALT	UG/L	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT
IRON	UG/L	1220.0	3480.0	6160.0	7680.0	1380.0	88.0
MAGNESIUM	UG/L	21200.0	3390.0	3750.0	5080.0	1460.0	110.0
MANGANESE	UG/L	200.0	110.0	170.0	180.0	48.0	10.0 LT
MOLYBDENUM	UG/L	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT
SODIUM	UG/L	131000.0	12200.0	9800.0	16700.0	6780.0	2000.0 LT
TIN	UG/L	110.0	30.0 LT	31.0	65.0	30.0 LT	30.0 LT
TITANIUM	UG/L	20.0 LT	20.0 LT	45.0	44.0	20.0 LT	20.0 LT
VANADIUM	UG/L	8.0	17.0	17.0	23.0	16.0	5.0 LT
YTTRIUM	UG/L	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT	5.0 LT
VOLATILE_ORGANICS___________							
CHLOROFORM	UG/L	13.9	5.4	ND	5.4	4.5	ND
TOLUENE	UG/L	86.0	397.0	216.0	937.0	1.5	9.9
ACRYLONITRILE	UG/L	37.0	ND	ND	ND	ND	ND
ETHYLBENZENE	UG/L	236.0	75.0	40.0	181.0	ND	2.3
METHYLENE CHLORIDE	UG/L	125.0	662.0	949.0	1174.0	174.0	11.9
TETRACHLOROETHENE	UG/L	39.0	178.0	168.0	353.0	ND	5.9
1,1,1-TRICHLOROETHANE	UG/L	ND	ND	2.4	2.0	ND	ND
1,1,2-TRICHLOROETHANE	UG/L	ND	ND	ND	ND	1.4	ND
1,2-DICHLOROETHANE	UG/L	ND	ND	3.1	ND	ND	ND
1,2-DICHLOROPROPANE	UG/L	ND	19.0	ND	ND	ND	ND
TRANS-1,2-DICHLOROETHENE	UG/L	2.1	2.8	1.7	5.4	ND	ND
TRICHLOROETHENE	UG/L	2.1	92.0	29.0	202.0	ND	ND
SEMI-VOLATILE_BASE/NEUTRALS_							
DIETHYLPHTHALATE	UG/L	4.2	ND	ND	ND	ND	ND
DI-N-OCTYL PHTHALATE	UG/L	5.2	ND	ND	ND	ND	ND
NAPHTHALENE	UG/L	3.4	8.6	11.2	19.0	ND	ND
BIS(2-ETHYLHEXYL)PHTHALATE	UG/L	52.0	20.0	32.0	19.0	ND	ND
DI-N-BUTYL PHTHALATE	UG/L	9.1	4.4	ND	4.3	ND	ND
SEMIVOLATILE_ACID__________							
2,4-DIMETHYLPHENOL	UG/L	828.0	95.0	119.0	112.0	ND	ND
PHENOL	UG/L	3400.0	296.0	319.0	667.0	ND	ND
PESTICIDE_EXTRACTABLES______							

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POLLUTANTS NOT LISTED WERE NOT DETECTED

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TABLE C-12

ST.LOUIS, MO   STORM EVENT THREE

POLLUTANT	UNITS	BRANCH WW BKGD 11109	BRANCH CSF 11110	BRANCH CSO 11111	BRANCH FIRST FLUSH 11112	BRANCH RUNOFF 11113	BRANCH PRECIP 11119
CONVENTIONAL/NONCONVENTIONAL							
BIOCHEMICAL OXYGEN DEMAND	MG/L	93.0	49.0	29.0	80.0	NS	15.0 LT
CHEMICAL OXYGEN DEMAND	MG/L	280.0	290.0	460.0	590.0	NS	25.0 LT
TOTAL ORGANIC CARBON	MG/L	91.0	NS	NS	NS	NS	6.5
NON-PARTICULATE TOC	MG/L	NS	25.0	17.0	46.0	NS	NS
TOTAL SOLIDS	MG/L	780.0	970.0	1706.0	858.0	NS	39.0
TOTAL VOLATILE SOLIDS	MG/L	232.0	199.0	316.0	261.0	NS	36.0
TOTAL VOL SUS SOLIDS	MG/L	54.0	90.0	218.0	132.0	NS	8.0
TOTAL SUSPENDED SOLIDS	MG/L	65.0	592.0	1440.0	432.0	NS	11.0
TOTAL VOL DIS SOLIDS	MG/L	178.0	109.0	98.0	129.0	NS	28.0
TOTAL DISSOLVED SOLIDS	MG/L	715.0	378.0	262.0	426.0	NS	28.0
SETTLEABLE SOLIDS	ML/L	1.0 LT	2.9	4.6	3.8	NS	1.0 LT
CHLORIDE	MG/L	83.0	76.0	63.0	59.0	NS	1.4
AMMONIA NITROGEN	MG/L	18.0	1.9	1.3	3.4	NS	1.0 LT
TOTAL PHENOL	UG/L	53.0	36.0	7.6	47.0	NS	27.0
OIL AND GREASE	MG/L	39.0	16.0	14.0	21.0	22.0	20.0 LT
METALS							
ANTIMONY	UG/L	4.0 LT	4.0 LT	4.0 LT	4.0 LT	NS	4.0 LT
ARSENIC	UG/L	3.0 LT	3.0 LT	1.0 LT	3.0 LT	NS	3.0 LT
BERYLLIUM	UG/L	2.0 LT	2.0 LT	2.0 LT	2.0 LT	NS	2.0 LT
CADMIUM	UG/L	23.0	27.0	28.0	30.0	NS	15.0
CHROMIUM	UG/L	91.0	55.0	68.0	59.0	NS	25.0 LT
COPPER	UG/L	54.0	111.0	148.0	119.0	NS	20.0 LT
LEAD	UG/L	200.0 LT	540.0	855.0	510.0	NS	200.0 LT
MERCURY	UG/L	1.0 LT	1.0 LT	1.0 LT	1.0 LT	NS	1.0 LT
NICKEL	UG/L	108.0	75.0 LT	82.0	75.0 LT	NS	75.0 LT
SELENIUM	UG/L	4.0 LT	4.0 LT	4.0 LT	4.0 LT	NS	4.0 LT
SILVER	UG/L	122.0	10.0 LT	10.0 LT	10.0 LT	NS	10.0 LT
THALLIUM	UG/L	75.0 LT	75.0 LT	75.0 LT	75.0 LT	NS	75.0 LT
ZINC	UG/L	52.0	399.0	610.0	400.0	NS	183.0
OTHERS							
CYANIDE	UG/L	20.0 LT	20.0 LT	20.0 LT	21.0	20.0 LT	20.0 LT
NONCONVENTIONAL METALS							
ALUMINUM	UG/L	578.0	9530.0	17600.0	4180.0	NS	105.0 LT
BARIUM	UG/L	46.0	161.0	259.0	99.0	NS	25.0 LT
BORON	UG/L	319.0	216.0	142.0	306.0	NS	21.0
CALCIUM	UG/L	50200.0	39400.0	35000.0	54000.0	NS	1860.0

LT = LESS THAN
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ND = NOT DETECTED
NS = NOT SAMPLED
POLLUTANTS NOT LISTED WERE NOT DETECTED

TABLE C-12

ST.LOUIS, MO STORM EVENT THREE

POLLUTANT	UNITS	BRANCH WW BKGD 11109	BRANCH CSF 11110	BRANCH CSO 11111	BRANCH FIRST FLUSH 11112	BRANCH RUNOFF 11113	BRANCH PRECIP 11119
COBALT	UG/L	35.0 LT	35.0 LT	35.0 LT	35.0 LT	NS	35.0 LT
IRON	UG/L	877.0	12700.0	22500.0	6570.0	NS	138.0
MAGNESIUM	UG/L	16300.0	8130.0	7680.0	9900.0	NS	319.0
MANGANESE	UG/L	152.0	464.0	771.0	347.0	NS	5.0
MOLYBDENUM	UG/L	40.0 LT	40.0 LT	40.0 LT	40.0 LT	NS	40.0 LT
SODIUM	UG/L	69400.0	66000.0	53200.0	55800.0	NS	5000.0 LT
TIN	UG/L	850.0 LT	850.0 LT	850.0 LT	850.0 LT	NS	850.0 LT
TITANIUM	UG/L	16.0	245.0	445.0	92.0	NS	12.0 LT
VANADIUM	UG/L	15.0 LT	37.0	49.0	15.0 LT	NS	15.0 LT
YTTRIUM	UG/L	12.0 LT	12.0 LT	16.0	12.0 LT	NS	12.0 LT
VOLATILE ORGANICS							
CHLOROFORM	UG/L	5.8	5.4	4.4	6.6	ND	3.5
TOLUENE	UG/L	5.3	2.7	ND	1.8	ND	1.6
ETHYLBENZENE	UG/L	1.2	ND	ND	ND	ND	ND
METHYLENE CHLORIDE	UG/L	165.0	13.0	14.0	22.0	8.2	6.2
TETRACHLOROETHENE	UG/L	ND	1.6	1.7	2.0	ND	ND
1,1,1-TRICHLOROETHANE	UG/L	6.0	72.0	33.0	48.0	ND	ND
1,2-DICHLOROPROPANE	UG/L	2.4	ND	ND	ND	ND	ND
TRANS-1,2-DICHLOROETHENE	UG/L	5.6	ND	ND	2.0	ND	ND
TRICHLOROETHENE	UG/L	1.9	1.6	ND	ND	ND	ND
SEMI-VOLATILE BASE/NEUTRALS							
FLUORANTHENE	UG/L	ND	ND	3.5	ND	NS	ND
PYRENE	UG/L	ND	ND	3.5	ND	NS	ND
1,2-DICHLOROBENZENE	UG/L	ND	ND	ND	6.0	NS	ND
NAPHTHALENE	UG/L	ND	ND	ND	3.2	NS	ND
BIS(2-ETHYLHEXYL)PHTHALATE	UG/L	ND	4.0	4.5	4.1	NS	1.0
SEMIVOLATILE ACID							
PESTICIDE EXTRACTABLES							

LT = LESS THAN
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TABLE C-12

ST.LOUIS, MO STORM EVENT THREE

POLLUTANT	UNITS	PRAIR WW BKGD 11114	PRAIR CSF 11115	PRAIR CSO 11116	PRAIR FIRST FLUSH 11117	PRAIR RUNOFF 11118	BRANCH PRECIP 11119
CONVENTIONAL/NONCONVENTIONAL							
BIOCHEMICAL OXYGEN DEMAND	MG/L	150.0	36.0	45.0	130.0	17.0	15.0 LT
CHEMICAL OXYGEN DEMAND	MG/L	340.0	310.0	310.0	250.0	25.0 LT	25.0 LT
TOTAL ORGANIC CARBON	MG/L	130.0	NS	NS	NS	NS	6.5
NON-PARTICULATE TOC	MG/L	NS	26.5	27.0	57.0	24.0	NS
TOTAL SOLIDS	MG/L	705.0	703.0	1200.0	1040.0	510.0	39.0
TOTAL VOLATILE SOLIDS	MG/L	230.0	174.0	179.0	263.0	120.0	36.0
TOTAL VOL SUS SOLIDS	MG/L	46.0	88.0	117.0	150.0	63.0	8.0
TOTAL SUSPENDED SOLIDS	MG/L	67.0	517.0	1060.0	759.0	365.0	11.0
TOTAL VOL DIS SOLIDS	MG/L	184.0	86.0	62.0	113.0	57.0	28.0
TOTAL DISSOLVED SOLIDS	MG/L	638.0	186.0	132.0	278.0	145.0	28.0
SETTLEABLE SOLIDS	ML/L	1.0 LT	1.8	3.3	8.9	1.0 LT	1.0 LT
CHLORIDE	MG/L	64.0	11.0	8.2	23.0	5.5	1.4
AMMONIA NITROGEN	MG/L	5.7	1.3	1.2	2.3	1.0 LT	1.0 LT
TOTAL PHENOL	UG/L	1900.0	700.0	700.0	2800.0	18.0	27.0
OIL AND GREASE	MG/L	84.0	26.0	17.0	35.0	22.0	20.0 LT
METALS							
ANTIMONY	UG/L	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT
ARSENIC	UG/L	3.0 LT	3.0 LT	3.0 LT	3.0 LT	3.0 LT	3.0 LT
BERYLLIUM	UG/L	2.0 LT	2.0 LT	2.0 LT	2.0 LT	2.0 LT	2.0 LT
CADMIUM	UG/L	16.0	33.0	589.0	32.0	26.0	15.0
CHROMIUM	UG/L	202.0	50.0	84.0	163.0	46.0	25.0 LT
COPPER	UG/L	139.0	120.0	180.0	203.0	99.0	20.0 LT
LEAD	UG/L	200.0 LT	477.0	909.0	744.0	437.0	200.0 LT
MERCURY	UG/L	1.0 LT	1.0 LT	1.0 LT	1.0 LT	1.0 LT	1.0 LT
NICKEL	UG/L	81.0	75.0 LT	154.0	117.0	75.0 LT	75.0 LT
SELENIUM	UG/L	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT
SILVER	UG/L	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT
THALLIUM	UG/L	75.0 LT	75.0 LT	75.0 LT	75.0 LT	75.0 LT	75.0 LT
ZINC	UG/L	354.0	452.0	679.0	663.0	462.0	183.0
OTHERS							
CYANIDE	UG/L	110.0	1300.0	1100.0	68.0	20.0 LT	20.0 LT
NONCONVENTIONAL METALS							
ALUMINUM	UG/L	789.0	2950.0	9030.0	10800.0	6630.0	105.0 LT
BARIUM	UG/L	28.0	123.0	214.0	223.0	139.0	25.0 LT
BORON	UG/L	468.0	133.0	265.0	259.0	155.0	21.0
CALCIUM	UG/L	43600.0	42500.0	56300.0	55500.0	62000.0	1860.0

LT = LESS THAN
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ND = NOT DETECTED
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POLLUTANTS NOT LISTED WERE NOT DETECTED

TABLE C-12

ST.LOUIS, MO   STORM EVENT THREE

POLLUTANT	UNITS	PRAIR WW BKGD 11114	PRAIR CSF 11115	PRAIR CSO 11116	PRAIR FIRST FLUSH 11117	PRAIR RUNOFF 11118	BRANCH PRECIP 11119
COBALT	UG/L	35.0 LT	35.0 LT	35.0 LT	35.0 LT	35.0 LT	35.0 LT
IRON	UG/L	949.0	6190.0	12900.0	17700.0	9740.0	138.0
MAGNESIUM	UG/L	16500.0	6860.0	8810.0	10500.0	4910.0	319.0
MANGANESE	UG/L	238.0	362.0	556.0	500.0	258.0	5.0
MOLYBDENUM	UG/L	40.0 LT	40.0 LT	40.0 LT	40.0 LT	40.0 LT	40.0 LT
SODIUM	UG/L	68500.0	14200.0	19100.0	34800.0	13700.0	5000.0 LT
TIN	UG/L	850.0 LT	850.0 LT	850.0 LT	850.0 LT	850.0 LT	850.0 LT
TITANIUM	UG/L	25.0	54.0	214.0	260.0	162.0	12.0 LT
VANADIUM	UG/L	15.0 LT	15.0 LT	15.0 LT	15.0 LT	15.0 LT	15.0 LT
YTTRIUM	UG/L	12.0 LT	12.0 LT	12.0 LT	12.0 LT	12.0 LT	12.0 LT
VOLATILE ORGANICS							
CHLOROFORM	UG/L	8.1	4.6	4.1	5.6	3.9	3.5
TOLUENE	UG/L	42.0	68.0	51.0	164.0	2.2	1.6
BENZENE	UG/L	ND	ND	1.2	2.0	ND	ND
ETHYLBENZENE	UG/L	5.1	23.0	11.0	57.0	ND	ND
METHYLENE CHLORIDE	UG/L	9.4	17.0	26.7	32.0	23.0	6.2
TETRACHLOROETHENE	UG/L	2.3	2.8	2.3	6.1	ND	ND
1,1,1-TRICHLOROETHANE	UG/L	1.3	ND	ND	1.4	ND	ND
TRANS-1,2-DICHLOROETHENE	UG/L	1.4	ND	ND	2.4	ND	ND
TRICHLOROETHENE	UG/L	2.0	ND	ND	ND	ND	ND
SEMI-VOLATILE BASE/NEUTRALS							
BENZO(B)FLUORANTHENE	UG/L	ND	4.0	ND	ND	4.0	ND
BENZO(A)PYRENE	UG/L	ND	7.0	ND	ND	ND	ND
CHRYSENE	UG/L	ND	ND	ND	ND	3.9	ND
FLUORANTHENE	UG/L	ND	4.0	ND	2.4	9.0	ND
HEXACHLOROETHANE	UG/L	ND	ND	ND	ND	8.0	ND
PYRENE	UG/L	ND	4.7	ND	3.6	ND	ND
BENZO(A)ANTHRACENE	UG/L	ND	ND	ND	ND	3.9	ND
1,2-DICHLOROBENZENE	UG/L	2.2	ND	ND	ND	ND	ND
NAPHTHALENE	UG/L	ND	ND	3.0	4.6	ND	ND
BIS(2-ETHYLHEXYL)PHTHALATE	UG/L	3.6	11.0	6.0	8.5	16.0	1.0
SEMIVOLATILE ACID							
4-CHLORO-3-METHYLPHENOL	UG/L	110.0	ND	ND	ND	ND	ND
2,4-DIMETHYLPHENOL	UG/L	ND	ND	90.0	169.0	ND	ND
PHENOL	UG/L	170.0	ND	74.0	159.0	ND	ND
PESTICIDE EXTRACTABLES							

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POLLUTANTS NOT LISTED WERE NOT DETECTED

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TABLE C-13

ST. PAUL, MN DRY WEATHER COMPOSITE

POLLUTANT	UNITS	EUS DW BKGD 10961	PHA SAN DW BKGD 10962	PHA STM COOL H2O 10963	EUS TAP WATER 10964
CONVENTIONAL/NONCONVENTIONAL					
BIOCHEMICAL OXYGEN DEMAND	MG/L	22.0 LT	800.0	22.0 LT	5.0 LT
CHEMICAL OXYGEN DEMAND	MG/L	270.0	2450.0	130.0	30.0
TOTAL ORGANIC CARBON	MG/L	NS	NS	9.5	14.0
NON-PARTICULATE TOC	MG/L	28.0	490.0	NS	NS
TOTAL SOLIDS	MG/L	189.0	1130.0	342.0	142.0
TOTAL VOLATILE SOLIDS	MG/L	34.0	664.0	72.0	24.0
TOTAL VOL SUS SOLIDS	MG/L	6.0	144.0	4.0	4.0 LT
TOTAL SUSPENDED SOLIDS	MG/L	23.0	340.0	4.0	4.0 LT
TOTAL VOL DIS SOLIDS	MG/L	28.0	520.0	68.0	24.0
TOTAL DISSOLVED SOLIDS	MG/L	166.0	788.0	338.0	142.0
SETTLEABLE SOLIDS	ML/L	1.0 LT	3.0	1.0 LT	1.0 LT
CHLORIDE	MG/L	29.0	13.0	35.0	10.0
AMMONIA NITROGEN	MG/L	6.8	7.8	1.0 LT	1.0 LT
TOTAL PHENOL	UG/L	40.0	38.0	8.0	7.0
OIL AND GREASE	MG/L	5.0 LT	15.0	5.0 LT	25.0
METALS					
ANTIMONY	UG/L	4.0 LT	4.0 LT	4.0 LT	4.0 LT
ARSENIC	UG/L	3.0 LT	3.0 LT	3.0 LT	3.0 LT
BERYLLIUM	UG/L	6.0	6.0	7.0	7.0
CADMIUM	UG/L	8.0	4.0	6.0	2.0 LT
CHROMIUM	UG/L	1540.0	22.0	18.0	8.0 LT
COPPER	UG/L	331.0	76.0	6.0 LT	13.0
LEAD	UG/L	617.0	160.0	158.0	53.0
MERCURY	UG/L	1.0 LT	1.0 LT	1.0 LT	1.0 LT
NICKEL	UG/L	40.0 LT	40.0 LT	46.0	40.0 LT
SELENIUM	UG/L	4.0 LT	4.0 LT	4.0 LT	4.0 LT
SILVER	UG/L	10.0 LT	7.0	7.0 LT	7.0 LT
THALLIUM	UG/L	100.0 LT	100.0 LT	100.0 LT	100.0 LT
ZINC	UG/L	230.0	102.0	9.0 LT	95.0
OTHERS					
CYANIDE	UG/L	20.0 LT	20.0 LT	20.0 LT	20.0 LT
NONCONVENTIONAL METALS					
ALUMINUM	UG/L	365.0	767.0	35.0 LT	910.0
BARIUM	UG/L	38.0	49.0	66.0	4.0 LT
BORON	UG/L	200.0	168.0	34.0 LT	34.0 LT
CALCIUM	UG/L	28300.0	46400.0	59400.0	468.0

LT = LESS THAN
GT = GREATER THAN
ND = NOT DETECTED
NS = NOT SAMPLED
POLLUTANTS NOT LISTED WERE NOT DETECTED

TABLE C-15

ST. PAUL, MN DRY WEATHER COMPOSITE

POLLUTANT	UNITS	EUS DW BKGD 10961	PHA SAN DW BKGD 10962	PHA STM COOL H2O 10963	EUS TAP WATER 10964
COBALT	UG/L	15.0	13.0	14.0	7.0 LT
IRON	UG/L	487.0	847.0	87.0	237.0
MAGNESIUM	UG/L	7990.0	16300.0	25100.0	114.0
MANGANESE	UG/L	37.0	161.0	306.0	6.0
MOLYBDENUM	UG/L	25.0 LT	25.0 LT	25.0 LT	28.0
SODIUM	UG/L	23900.0	46800.0	9260.0	37400.0
TIN	UG/L	3960.0	6950.0	8900.0	715.0 LT
TITANIUM	UG/L	6.0	6.0	3.0	5.0
VANADIUM	UG/L	16.0 LT	16.0 LT	30.0	16.0 LT
YTTRIUM	UG/L	5.0	4.0	2.0 LT	2.0 LT
VOLATILE ORGANICS					
CHLOROFORM	UG/L	ND	ND	ND	10.1
TOLUENE	UG/L	ND	2.3	ND	ND
METHYLENE CHLORIDE	UG/L	12.5	30.0	23.5	24.3
1,1,1-TRICHLOROETHANE	UG/L	2.8	ND	ND	ND
TRICHLOROETHENE	UG/L	ND	3.2	ND	ND
SEMI-VOLATILE BASE/NEUTRALS					
DIETHYLPHTHALATE	UG/L	5.4	4.8	ND	ND
BIS(2-ETHYLHEXYL)PHTHALATE	UG/L	7.3	16.0 ND	4.5	3.6
SEMIVOLATILE ACID					
4-CHLORO-3-METHYLPHENOL	UG/L	ND	8.1	ND	ND
PESTICIDE EXTRACTABLES					

LT = LESS THAN
GT = GREATER THAN
ND = NOT DETECTED
NS = NOT SAMPLED
POLLUTANTS NOT LISTED WERE NOT DETECTED

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TABLE C-14

ST. PAUL, MN STORM EVENT ONE

POLLUTANT	UNITS	EUS WW BKGD 10965	EUS CSF 10966	EUS CSO 10967	EUS FIRST FLUSH 10968	EUS RUNOFF 10969	EUS PRECIP 10976
CONVENTIONAL/NONCONVENTIONAL							
BIOCHEMICAL OXYGEN DEMAND	MG/L	26.0	15.0 LT	15.0	17.0	15.0 LT	NS
CHEMICAL OXYGEN DEMAND	MG/L	76.0	96.0	140.0	130.0	34.0	NS
TOTAL ORGANIC CARBON	MG/L	43.5	NS	NS	NS	NS	NS
NON-PARTICULATE TOC	MG/L	NS	16.5	14.5	17.0	14.5	NS
TOTAL SOLIDS	MG/L	278.0	210.0	249.0	240.0	51.0	NS
TOTAL VOLATILE SOLIDS	MG/L	88.0	93.0	95.0	111.0	11.0	NS
TOTAL VOL SUS SOLIDS	MG/L	27.0	61.0	63.0	62.0	4.0	NS
TOTAL SUSPENDED SOLIDS	MG/L	32.0	137.0	189.0	152.0	15.0	NS
TOTAL VOL DIS SOLIDS	MG/L	61.0	32.0	32.0	49.0	7.0	NS
TOTAL DISSOLVED SOLIDS	MG/L	246.0	73.0	60.0	88.0	36.0	NS
SETTLEABLE SOLIDS	ML/L	1.0 LT	1.1	2.1	1.8	1.0 LT	NS
CHLORIDE	MG/L	120.0	24.0	11.0	27.0	8.1	NS
AMMONIA NITROGEN	MG/L	12.0	1.7	1.0	1.8	1.0 LT	NS
TOTAL PHENOL	UG/L	7.8	9.7	9.7	8.1	6.5	NS
OIL AND GREASE	MG/L	10.0 LT	6.0	8.0	8.0	5.0 LT	NS
METALS							
ANTIMONY	UG/L	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT
ARSENIC	UG/L	3.0 LT	3.0 LT	3.0 LT	3.0 LT	3.0 LT	3.0 LT
BERYLLIUM	UG/L	2.0 LT	2.0 LT	2.0 LT	2.0 LT	2.0 LT	2.0 LT
CADMIUM	UG/L	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT
CHROMIUM	UG/L	20.0 LT	20.0 LT	20.0 LT	20.0 LT	20.0 LT	20.0 LT
COPPER	UG/L	40.0 LT	40.0 LT	40.0 LT	40.0 LT	40.0 LT	40.0 LT
LEAD	UG/L	150.0 LT	393.0	388.0	244.0	150.0 LT	150.0 LT
MERCURY	UG/L	1.0 LT	1.0 LT	1.0 LT	1.0 LT	1.0 LT	1.0 LT
NICKEL	UG/L	60.0 LT	60.0 LT	60.0 LT	60.0 LT	60.0 LT	60.0 LT
SELENIUM	UG/L	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT
SILVER	UG/L	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT
THALLIUM	UG/L	100.0 LT	100.0 LT	100.0 LT	100.0 LT	100.0 LT	100.0 LT
ZINC	UG/L	85.0	163.0	294.0	264.0	74.0	23.0
OTHERS							
CYANIDE	UG/L	38.0	20.0 LT	20.0 LT	20.0 LT	20.0 LT	NS
NONCONVENTIONAL METALS							
ALUMINUM	UG/L	373.0	2370.0	4060.0	3050.0	807.0	180.0 LT
BARIUM	UG/L	44.0	40.0	70.0	69.0	10.0 LT	10.0 LT
BORON	UG/L	30.0 LT	30.0 LT	30.0 LT	30.0 LT	30.0 LT	30.0 LT
CALCIUM	UG/L	28600.0	12100.0	14800.0	14000.0	6160.0	410.0

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TABLE C-14

ST. PAUL, MN STORM EVENT ONE

POLLUTANT	UNITS	EUS WW BKGD 10965	EUS CSF 10966	EUS CSO 10967	EUS FIRST FLUSH 10968	EUS RUNOFF 10969	EUS PRECIP 10976
COBALT	UG/L	13.0	6.0	16.0	8.0 LT	6.0	5.0 LT
IRON	UG/L	434.0	3760.0	7730.0	6370.0	616.0	35.0 LT
MAGNESIUM	UG/L	6260.0	3590.0	6170.0	5370.0	1000.0	68.0
MANGANESE	UG/L	44.0	110.0	184.0	150.0	21.0	39.0
MOLYBDENUM	UG/L	35.0 LT	35.0 LT	35.0 LT	35.0 LT	35.0 LT	35.0 LT
SODIUM	UG/L	24200.0	5000.0 LT	5000.0 LT	5000.0 LT	5000.0 LT	5000.0 LT
TIN	UG/L	450.0 LT	450.0 LT	450.0 LT	450.0 LT	450.0 LT	450.0 LT
TITANIUM	UG/L	12.0 LT	69.0	159.0	121.0	12.0 LT	12.0 LT
VANADIUM	UG/L	25.0 LT	25.0 LT	25.0 LT	25.0 LT	25.0 LT	25.0 LT
YTTRIUM	UG/L	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT
VOLATILE ORGANICS							
CHLOROFORM	UG/L	8.8	ND	4.7	ND	ND	NS
TOLUENE	UG/L	ND	1.0	1.0	1.3	ND	NS
METHYLENE CHLORIDE	UG/L	9.8	7.5	8.6	7.4	23.2	NS
SEMI-VOLATILE BASE/NEUTRALS							
BENZO(K)FLUORANTHENE	UG/L	ND	3.0	6.1	5.0	ND	NS
BENZO(A)PYRENE	UG/L	ND	ND	4.5	5.6	ND	NS
FLUORANTHENE	UG/L	ND	ND	6.9	5.3	ND	NS
PHENANTHRENE	UG/L	ND	ND	3.8	ND	ND	NS
PYRENE	UG/L	ND	ND	5.8	5.0	ND	NS
BENZO(A)ANTHRACENE	UG/L	ND	ND	4.0	4.0	ND	NS
BIS(2-ETHYLHEXYL)PHTHALATE	UG/L	36.0	33.0	36.0	34.0	ND	NS
DI-N-BUTYL PHTHALATE	UG/L	73.0	11.0	10.7	16.0	ND	NS
SEMIVOLATILE ACID							
PESTICIDE EXTRACTABLES							

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TABLE C-14

ST. PAUL, MN STORM EVENT ONE

POLLUTANT	UNITS	PHA SAN WW 9KGD 10982	PHA SAN CSF 10983	PHA SAN CSO 10984	PHA SAN FIRST FLUSH 10985	PHA SAN RUNOFF 10986	PHA STM SS FL 10987	PHA PRECIP 10988
CONVENTIONAL/NONCONVENTIONAL								
BIOCHEMICAL OXYGEN DEMAND	MG/L	NS	NS	NS	NS	15.0 LT	NS	15.0 LT
CHEMICAL OXYGEN DEMAND	MG/L	940.0	250.0	210.0	270.0	35.0	240.0	150.0
TOTAL ORGANIC CARBON	MG/L	NS	NS	NS	NS	NS	31.0	14.0
NON-PARTICULATE TOC	MG/L	210.0	57.0	54.0	59.0	13.0	NS	NS
TOTAL SOLIDS	MG/L	880.0	247.0	880.0	390.0	188.0	277.0	62.0
TOTAL VOLATILE SOLIDS	MG/L	501.0	131.0	97.0	270.0	52.0	82.0	27.0
TOTAL VOL SUS SOLIDS	MG/L	337.0	65.0	75.0	228.0	32.0	44.0	4.0 LT
TOTAL SUSPENDED SOLIDS	MG/L	478.0	125.0	160.0	273.0	127.0	111.0	4.0 LT
TOTAL VOL DIS SOLIDS	MG/L	164.0	66.0	22.0	42.0	20.0	38.0	24.0
TOTAL DISSOLVED SOLIDS	MG/L	402.0	122.0	112.0	117.0	61.0	166.0	60.0
SETTLEABLE SOLIDS	ML/L	18.0	1.7	2.9	4.0	1.0 LT	4.0	1.0 LT
CHLORIDE	MG/L	22.0	3.8	3.8	9.8	2.3	3.8	.7
AMMONIA NITROGEN	MG/L	10.0	1.0 LT	1.0 LT	3.1	1.0 LT	1.0 LT	1.0 LT
TOTAL PHENOL	UG/L	33.0	37.0	35.0	26.0	16.0	12.0	12.0
OIL AND GREASE	MG/L	58.0	11.0	15.0	16.0	10.0 LT	NS	10.0 LT
METALS								
ANTIMONY	UG/L	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT
ARSENIC	UG/L	3.0 LT	3.0 LT	3.0 LT	3.0 LT	3.0 LT	3.0 LT	3.0 LT
BERYLLIUM	UG/L	2.0 LT	2.0 LT	2.0 LT	2.0 LT	2.0 LT	2.0 LT	2.0 LT
CADMIUM	UG/L	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT
CHROMIUM	UG/L	20.0 LT	20.0 LT	20.0 LT	20.0 LT	20.0 LT	20.0 LT	20.0 LT
COPPER	UG/L	71.0	40.0 LT	40.0 LT	40.0 LT	40.0 LT	40.0 LT	40.0 LT
LEAD	UG/L	202.0	150.0 LT	150.0 LT	150.0 LT	150.0 LT	150.0 LT	150.0 LT
MERCURY	UG/L	1.0 LT	1.0 LT	1.0 LT	1.0 LT	1.0 LT	1.0 LT	1.0 LT
NICKEL	UG/L	60.0 LT	60.0 LT	60.0 LT	60.0 LT	60.0 LT	60.0 LT	60.0 LT
SELENIUM	UG/L	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT
SILVER	UG/L	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT
THALLIUM	UG/L	100.0 LT	100.0 LT	100.0 LT	100.0 LT	100.0 LT	100.0 LT	100.0 LT
ZINC	UG/L	595.0	126.0	137.0	304.0	136.0	103.0	65.0
OTHERS								
CYANIDE	UG/L	20.0 LT	20.0 LT	20.0 LT	20.0 LT	20.0 LT	20.0 LT	20.0 LT
NONCONVENTIONAL METALS								
ALUMINUM	UG/L	5840.0	2790.0	3040.0	3880.0	3410.0	1690.0	224.0
BARIUM	UG/L	129.0	34.0	43.0	99.0	45.0	49.0	10.0 LT
BORON	UG/L	176.0	30.0 LT	30.0 LT	40.0	30.0 LT	30.0 LT	30.0 LT
CALCIUM	UG/L	41300.0	10400.0	10100.0	17400.0	11500.0	28800.0	1620.0

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TABLE C-14
ST. PAUL, MN STORM EVENT ONE

POLLUTANT	UNITS	PHA SAN WW BKGD 10982	PHA SAN CSF 10983	PHA SAN CSO 10984	PHA SAN FIRST FLUSH 10985	PHA SAN RUNOFF 10986	PHA STM SS FL 10987	PHA PRECIP 10988
COBALT	UG/L	8.0	5.0 LT	5.0 LT	5.0 LT	5.0 LT	9.0	5.0 LT
IRON	UG/L	6340.0	4910.0	5130.0	6180.0	5550.0	2280.0	128.0
MAGNESIUM	UG/L	14800.0	4190.0	4130.0	7140.0	3550.0	11800.0	250.0
MANGANESE	UG/L	281.0	141.0	148.0	215.0	178.0	241.0	3.0 LT
MOLYBDENUM	UG/L	35.0 LT	35.0 LT	35.0 LT	35.0 LT	35.0 LT	35.0 LT	35.0 LT
SODIUM	UG/L	50700.0	5000.0 LT	5000.0 LT	5000.0 LT	5000.0 LT	5000.0 LT	5000.0 LT
TIN	UG/L	450.0 LT	450.0 LT	450.0 LT	450.0 LT	450.0 LT	450.0 LT	450.0 LT
TITANIUM	UG/L	114.0	83.0	83.0	115.0	120.0	32.0	12.0 LT
VANADIUM	UG/L	25.0 LT	25.0 LT	25.0 LT	25.0 LT	25.0 LT	25.0 LT	25.0 LT
YTTRIUM	UG/L	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT
VOLATILE ORGANICS								
CHLOROFORM	UG/L	7.0	ND	4.5	5.0	ND	ND	NS
TOLUENE	UG/L	24.3	2.1	2.1	2.4	ND	ND	NS
ETHYLBENZENE	UG/L	10.2	ND	ND	ND	ND	ND	NS
BROMOMETHANE	UG/L	9.2	ND	ND	ND	ND	ND	NS
CHLOROMETHANE	UG/L	14.3	ND	ND	ND	ND	ND	NS
METHYLENE CHLORIDE	UG/L	38.0	13.0	12.1	20.0	10.8	11.2	NS
TETRACHLOROETHENE	UG/L	ND	ND	ND	1.6	ND	ND	NS
SEMI-VOLATILE BASE/NEUTRALS								
FLUORANTHENE	UG/L	ND	ND	ND	6.1	ND	ND	NS
PHENANTHRENE	UG/L	ND	33.0	ND	3.8	ND	ND	NS
BIS(2-ETHYLHEXYL)PHTHALATE	UG/L	ND	13.0	11.0	26.0	11.0	12.0	NS
DI-N-BUTYL PHTHALATE	UG/L	ND	ND	ND	3.7	ND	ND	NS
SEMIVOLATILE ACID								
PESTICIDE EXTRACTABLES								

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TABLE C-15

ST. PAUL. MN STORM EVENT TWO

POLLUTANT	UNITS	PHA SAN WW BKGD 10970	PHA SAN CSF 10971	PHA SAN CSO 10972	PHA SAN FIRST FLUSH 10973	PHA SAN RUNOFF 10974	PHA STM SS FL 10975
CONVENTIONAL/NONCONVENTIONAL							
BIOCHEMICAL OXYGEN DEMAND	MG/L	240.0	150.0	180.0	210.0	16.0	15.0 LT
CHEMICAL OXYGEN DEMAND	MG/L	790.0	430.0	400.0	700.0	130.0	78.0
TOTAL ORGANIC CARBON	MG/L	200.0	150.0	170.0	180.0	32.0	36.0
TOTAL SOLIDS	MG/L	723.0	399.0	489.0	592.0	230.0	264.0
TOTAL VOLATILE SOLIDS	MG/L	398.0	195.0	285.0	308.0	136.0	130.0
TOTAL VOL SUS SOLIDS	MG/L	215.0	125.0	168.0	201.0	27.0	15.0
TOTAL SUSPENDED SOLIDS	MG/L	398.0	235.0	305.0	381.0	114.0	21.0
TOTAL VOL DIS SOLIDS	MG/L	183.0	70.0	117.0	107.0	109.0	115.0
TOTAL DISSOLVED SOLIDS	MG/L	325.0	164.0	183.0	211.0	116.0	243.0
SETTLEABLE SOLIDS	ML/L	11.0	7.3	8.8	7.8	1.0 LT	1.0 LT
CHLORIDE	MG/L	29.0	13.0	9.1	19.0	3.5	9.1
AMMONIA NITROGEN	MG/L	7.8	3.9	3.5	4.8	1.0 LT	1.0 LT
TOTAL PHENOL	UG/L	NS	89.0	77.0	39.0	690.0	8.5
OIL AND GREASE	MG/L	31.0	25.0	19.0	25.0	14.0	5.0 LT
METALS________________________							
ANTIMONY	UG/L	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT
ARSENIC	UG/L	3.0 LT	3.0 LT	3.0 LT	3.0 LT	3.0 LT	3.0 LT
BERYLLIUM	UG/L	2.0 LT	2.0 LT	2.0 LT	2.0 LT	2.0 LT	2.0 LT
CADMIUM	UG/L	18.0	15.0	15.0	17.0	15.0 LT	17.0
CHROMIUM	UG/L	52.0	40.0 LT	40.0 LT	40.0 LT	42.0	40.0 LT
COPPER	UG/L	130.0	94.0	91.0	106.0	60.0	57.0
LEAD	UG/L	264.0	192.0	201.0	282.0	205.0	180.0 LT
MERCURY	UG/L	1.0 LT	1.0 LT	1.0 LT	1.0 LT	1.0 LT	1.0 LT
NICKEL	UG/L	138.0	99.0	91.0	91.0	83.0	201.0
SELENIUM	UG/L	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT
SILVER	UG/L	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT
THALLIUM	UG/L	70.0 LT	70.0 LT	70.0 LT	70.0 LT	70.0 LT	70.0 LT
ZINC	UG/L	399.0	234.0	243.0	311.0	158.0	63.0
OTHERS________________________							
CYANIDE	UG/L	25.0	20.0 LT	20.0 LT	20.0 LT	20.0 LT	20.0 LT
NONCONVENTIONAL METALS______							
ALUMINUM	UG/L	5070.0	4110.0	3680.0	4780.0	3480.0	749.0
BARIUM	UG/L	165.0	95.0	95.0	123.0	62.0	77.0
BORON	UG/L	244.0	111.0	44.0	80.0	20.0 LT	99.0
CALCIUM	UG/L	41200.0	20300.0	19300.0	27100.0	9510.0	49300.0
COBALT	UG/L	35.0	30.0 LT	30.0 LT	38.0	30.0 LT	37.0

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TABLE C-15
ST. PAUL, MN STORM EVENT TWO

POLLUTANT	UNITS	PHA SAN WW BKGD 10970	PHA SAN CSF 10971	PHA SAN CSO 10972	PHA SAN FIRST FLUSH 10973	PHA SAN RUNOFF 10974	PHA STM SS FL 10975
IRON	UG/L	7160.0	5160.0	5450.0	6180.0	5670.0	663.0
MAGNESIUM	UG/L	10900.0	6730.0	6500.0	8460.0	2810.0	21800.0
MANGANESE	UG/L	289.0	189.0	199.0	232.0	194.0	265.0
MOLYBDENUM	UG/L	45.0 LT	45.0 LT	45.0 LT	45.0 LT	45.0 LT	45.0 LT
SODIUM	UG/L	45200.0	33100.0	25800.0	46200.0	11900.0	23300.0
TIN	UG/L	850.0 LT	850.0 LT	850.0 LT	850.0 LT	850.0 LT	850.0 LT
TITANIUM	UG/L	157.0	128.0	130.0	139.0	179.0	38.0
VANADIUM	UG/L	20.0 LT	20.0 LT	20.0 LT	20.0 LT	20.0 LT	20.0 LT
YTTRIUM	UG/L	15.0 LT	15.0 LT	15.0 LT	15.0 LT	15.0 LT	15.0 LT
VOLATILE ORGANICS							
CHLOROFORM	UG/L	ND	11.0	7.8	7.9	4.8	5.1
TOLUENE	UG/L	ND	5.2	4.6	7.0	2.9	ND
METHYLENE CHLORIDE	UG/L	ND	20.0	21.0	41.0	8.9	16.0
TETRACHLOROETHENE	UG/L	ND	1.9	ND	ND	ND	ND
1,2-DICHLOROPROPANE	UG/L	ND	3.8	3.2	11.0	ND	1.5
SEMI-VOLATILE BASE/NEUTRALS							
ANTHRACENE	UG/L	ND	ND	ND	4.8	ND	ND
FLUORANTHENE	UG/L	ND	ND	14.0	8.8	5.8	ND
BENZO(A)ANTHRACENE	UG/L	ND	ND	5.9	4.0	ND	ND
BIS(2-ETHYLHEXYL)PHTHALATE	UG/L	ND	24.0	24.0	32.0	11.0	ND
SEMIVOLATILE ACID							
2,4-DICHLOROPHENOL	UG/L	ND	ND	9.2	ND	ND	ND
2,4-DIMETHYLPHENOL	UG/L	5.6	ND	ND	ND	7.0	ND
PHENOL	UG/L	ND	ND	9.0	ND	952.0	ND
PENTACHLOROPHENOL	UG/L	ND	ND	11.0	6.6	ND	ND
PESTICIDE EXTRACTABLES							

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TABLE C-15

ST. PAUL, MN   STORM EVENT TWO

POLLUTANT	UNITS	EUS CSF 10978	EUS CSO 10979	EUS FIRST FLUSH 10980	EUS RUNOFF 10981	EUS PRECIP 11000
CONVENTIONAL/NONCONVENTIONAL						
BIOCHEMICAL OXYGEN DEMAND	MG/L	15.0 LT	15.0 LT	80.0	15.0 LT	15.0 LT
CHEMICAL OXYGEN DEMAND	MG/L	77.0	67.0	320.0	60.0	25.0 LT
TOTAL ORGANIC CARBON	MG/L	29.0	22.0	150.0	12.0	5.0 LT
TOTAL SOLIDS	MG/L	123.0	165.0	334.0	50.0	50.0
TOTAL VOLATILE SOLIDS	MG/L	67.0	101.0	143.0	38.0	55.0
TOTAL VOL SUS SOLIDS	MG/L	24.0	30.0	105.0	9.0	5.0
TOTAL SUSPENDED SOLIDS	MG/L	78.0	93.0	230.0	17.0	4.0 LT
TOTAL VOL DIS SOLIDS	MG/L	43.0	71.0	38.0	29.0	50.0
TOTAL DISSOLVED SOLIDS	MG/L	45.0	72.0	104.0	33.0	50.0
SETTLEABLE SOLIDS	ML/L	1.0 LT	1.0 LT	7.4	1.0 LT	1.0 LT
CHLORIDE	MG/L	3.5	2.1	23.0	.7	.7
AMMONIA NITROGEN	MG/L	1.0 LT	1.0 LT	11.0	1.0 LT	1.0 LT
TOTAL PHENOL	UG/L	7.5	7.8	30.0	11.0	5.2
OIL AND GREASE	MG/L	10.0 LT	10.0 LT	16.0	10.0 LT	10.0 LT
METALS						
ANTIMONY	UG/L	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT
ARSENIC	UG/L	3.0 LT	3.0 LT	3.0 LT	3.0 LT	3.0 LT
BERYLLIUM	UG/L	2.0 LT	2.0 LT	2.0 LT	2.0 LT	2.0 LT
CADMIUM	UG/L	12.0 LT	12.0 LT	12.0 LT	12.0 LT	12.0 LT
CHROMIUM	UG/L	29.0	38.0	340.0	25.0 LT	25.0 LT
COPPER	UG/L	38.0	32.0	227.0	20.0 LT	20.0 LT
LEAD	UG/L	306.0	417.0	481.0	200.0 LT	200.0 LT
MERCURY	UG/L	1.0 LT	1.0 LT	1.0 LT	1.0 LT	1.0 LT
NICKEL	UG/L	75.0 LT	75.0 LT	79.0	75.0 LT	75.0 LT
SELENIUM	UG/L	4.0 LT	4.0 LT	4.0 LT	4.0 LT	4.0 LT
SILVER	UG/L	10.0 LT	10.0 LT	10.0 LT	10.0 LT	10.0 LT
THALLIUM	UG/L	75.0 LT	75.0 LT	75.0 LT	75.0 LT	75.0 LT
ZINC	UG/L	139.0	153.0	416.0	99.0	5.0 LT
OTHERS						
CYANIDE	UG/L	20.0 LT	20.0 LT	20.0 LT	20.0 LT	NS
NONCONVENTIONAL METALS						
ALUMINUM	UG/L	2080.0	2510.0	3010.0	573.0	105.0 LT
BARIUM	UG/L	43.0	44.0	72.0	25.0 LT	25.0 LT
BORON	UG/L	32.0	10.0 LT	93.0	10.0 LT	63.0
CALCIUM	UG/L	8580.0	8010.0	23000.0	4090.0	262.0
COBALT	UG/L	35.0 LT	35.0 LT	35.0 LT	35.0 LT	35.0 LT

LT = LESS THAN
GT = GREATER THAN
ND = NOT DETECTED
NS = NOT SAMPLED
POLLUTANTS NOT LISTED WERE NOT DETECTED

TABLE C-15
ST. PAUL, MN. STORM EVENT TWO

POLLUTANT	UNITS	EUS CSF 10978	EUS CSO 10979	EUS FIRST FLUSH 10980	EUS RUNOFF 10981	EUS PRECIP 11000
IRON	UG/L	3530.0	4130.0	6070.0	1230.0	40.0 LT
MAGNESIUM	UG/L	3060.0	3160.0	8310.0	889.0	39.0
MANGANESE	UG/L	118.0	129.0	206.0	40.0	3.0 LT
MOLYBDENUM	UG/L	40.0 LT	40.0 LT	40.0 LT	40.0 LT	40.0 LT
SODIUM	UG/L	8440.0	5000.0 LT	25400.0	5000.0 LT	5000.0 LT
TIN	UG/L	850.0 LT	850.0 LT	850.0 LT	850.0 LT	850.0 LT
TITANIUM	UG/L	87.0	98.0	118.0	27.0	12.0 LT
VANADIUM	UG/L	15.0 LT	15.0 LT	15.0 LT	15.0 LT	15.0 LT
YTTRIUM	UG/L	12.0 LT	12.0 LT	12.0 LT	12.0 LT	12.0 LT
VOLATILE_ORGANICS____________						
TOLUENE	UG/L	1.7	ND	ND	ND	ND
METHYLENE CHLORIDE	UG/L	17.0	6.7	15.0	14.0	26.0
TETRACHLOROETHENE	UG/L	ND	ND	12.0	ND	ND
SEMI-VOLATILE_BASE/NEUTRALS_						
BENZO(B)FLUORANTHENE	UG/L	2.0	2.0	3.0	ND	ND
BENZO(A)PYRENE	UG/L	ND	ND	2.5	ND	ND
BIS(2-CHLOROISOPROPYL)ETHER	UG/L	ND	ND	7.0	ND	ND
FLUORANTHENE	UG/L	ND	ND	5.9	ND	ND
PYRENE	UG/L	ND	ND	4.0	ND	ND
BENZO(A)ANTHRACENE	UG/L	ND	ND	4.0	ND	ND
BIS(2-ETHYLHEXYL)PHTHALATE	UG/L	7.0	6.7	21.0	4.0	ND
SEMIVOLATILE_ACID___________						
2,4-DIMETHYLPHENOL	UG/L	ND	ND	6.0	ND	ND
PESTICIDE_EXTRACTABLES______						

LT = LESS THAN
GT = GREATER THAN
ND = NOT DETECTED
NS = NOT SAMPLED
POLLUTANTS NOT LISTED WERE NOT DETECTED

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TABLE C-16

SEDIMENT RESULTS

		St. Paul		Seattle		Providence	
Pollutant	Units	Eustis	Phalen	Lander	Michigan	Ernest at Allens	Interceptor Line
Metals							
Antimony	µg/kg	3,000	<400	2,600	1,900	4,900	640
Arsenic	µg/kg	1,700	3,200	27,000	11,000	290,000	3,600
Beryllium	µg/kg	70	70	110	460	170	210
Cadmium	µg/kg	360	260	600	4,800	320	4,400
Chromium	µg/kg	310,000	27,000	6,000	31,000	32,000	120,000
Copper	µg/kg	81,000	26,000	480,000	110,000	150,000	500,000
Lead	µg/kg	200,000	490,000	140,000	260,000	80,000	330,000
Mercury	µg/kg	15	2,800	110	1,400	17,00	1,200
Nickel	µg/kg	33,000	7,000	26,000	37,000	96,000	74,000
Selenium	µg/kg	<400	<400	<500	<500	<200	<10,000
Silver	µg/kg	640	1,100	460	3,200	2,000	520
Thallium	µg/kg	<2,000	<200	<200	<200	<70	<400
Zinc	µg/kg	96,000	100,000	140,000	320,000	240,000	1,000,000
Others							
Cyanide	µg/kg	<12,000	<45,000	1,400	7,500	12,400	3,400
TOC	µg/kg	98	204	4,800	1,500	8,400	>10,000
COD	µg/kg	10,000	15,000	60,000	180,000	44,000	66,000
Volatiles							
1,1-dichloroethane	µg/kg	ND	ND	ND	150	75	ND
Trichloroethene	µg/kg	ND	ND	ND	ND	78	ND
1,1,1-trichloroethane	µg/kg	ND	ND	ND	570	ND	630
1,1-dichloroethene	µg/kg	ND	ND	ND	57	ND	ND
Toluene	µg/kg	ND	ND	ND	300	ND	3,400
1,2-trans-dichloroethylene	µg/kg	ND	ND	ND	ND	ND	490
Ethylbenzene	µg/kg	ND	ND	ND	ND	ND	530
Acids							
Base/Neutrals							
Napthalene	µg/kg	2,600	ND	ND	ND	ND	1,200
Bis(2-ethylhexyl)phthalate	µg/kg	380	1,400	ND	960	ND	38,000
Butyl benzyl phthalate	µg/kg	78	310	ND	ND	ND	1,200
Benzo(a)anthracene	µg/kg	2,400	340	ND	ND	ND	1,400
Benzo(a)pyrene	µg/kg	1,100	210	ND	ND	ND	1,600
Benzo(k)fluoranthene	µg/kg	8,700	1,400	ND	ND	ND	ND
Chrysene	µg/kg	5,400	910	ND	ND	ND	1,100
Anthracene	µg/kg	450	92	ND	ND	62	880
Fluorene	µg/kg	1,000	ND	ND	ND	ND	790
Phenanthrene	µg/kg	4,300	510	ND	ND	380	3,800
Dibenzo(a,h)anthracene	µg/kg	320	150	ND	ND	ND	ND
Benzo(g,h,i)perylene	µg/kg	ND	86	ND	ND	ND	ND
Fluoranthene	µg/kg	ND	ND	ND	ND	460	3,300
Pyrene	µg/kg	ND	ND	ND	ND	460	2,800
N-nitrosodiphenylamine	µg/kg	ND	ND	1,900	ND	ND	ND
Di-n-butyl phthalate	µg/kg	ND	ND	870	ND	ND	ND
Acenaphtheme	µg/kg	ND	ND	ND	ND	ND	360
1,2,4-tricholorobenzene	µg/kg	ND	ND	ND	ND	ND	400
1,4-dicholorobenzene	µg/kg	ND	ND	ND	ND	ND	2,700

Pollutants not listed were not detected.

APPENDIX D
QUALITY ASSURANCE/QUALITY CONTROL RESULTS

TABLE D-1. PERCENT RECOVERIES - WASTEWATER VOLATILE ORGANIC POLLUTANTS

Surrogate	Providence [Mean ± σ (*)]	Seattle [Mean ± σ (*)]	St. Louis [Mean ± σ (*)]	St. Paul [Mean ± σ (*)]	Total [Mean ± σ (*)]
A. Method Spike					
Acrylonitrile-d_3	90 ± 17 (6)		76 ± 9 (4)	93 ± 26 (5)	87 ± 18 (15)
Benzene-d_6	102 ± 13 (6)		114 ± 18 (4)	97 ± 26 (5)	104 ± 19 (15)
Carbon-^{13}C Tetrachloride	85 ± 14 (6)		95 ± 8 (4)	100 ± 15 (5)	93 ± 13 (15)
Chlorobenzene-d_5	101 ± 9 (6)		110 ± 13 (4)	102 ± 6 (5)	104 ± 9 (15)
1,2-Dichloroethane-d_4	82 ± 5 (6)	79 ± 13 (3)	99 ± 13 (4)	103 ± 9 (5)	91 ± 9 (18)
1,1,1-Trichloroethane-d_3	86 ± 14 (6)		91 ± 8 (4)	92 ± 10 (5)	89 ± 11 (15)
1,1-Dichloroethane-2,2,2-d_3	91 ± 14 (6)		98 ± 10 (4)	99 ± 8 (5)	96 ± 11 (15)
1,1,2-Trichloroethane-$^{13}C_2$	97 ± 16 (6)		106 ± 19 (4)	108 ± 8 (5)	103 ± 14 (15)
1,1,2,2-Tetrachloroethane-d_2	91 ± 8 (6)		84 ± 5 (4)	84 ± 10 (5)	87 ± 8 (15)
Chloroform-^{13}C	87 ± 16 (6)		93 ± 10 (4)	92 ± 10 (5)	90 ± 12 (15)
1,1-Dichloroethylene-d_2	91 ± 15 (6)		99 ± 13 (4)	99 ± 9 (5)	96 ± 12 (15)
1,2-Dichloropropane-d_6	99 ± 14 (6)		111 ± 18 (4)	111 ± 7 (5)	106 ± 13 (15)
Ethylbenzene-d_{10}	100 ± 7 (6)	89 ± 2 (2)	108 ± 13 (4)	103 ± 6 (5)	101 ± 8 (17)
Methylene Chloride-d_2	97 ± 10 (6)		99 ± 11 (4)	101 ± 7 (5)	99 ± 9 (15)
Bromoform-^{13}C	89 ± 10 (6)		80 ± 4 (4)	80 ± 9 (5)	84 ± 8 (15)
Toluene-2,3,4,5,6-d_5	102 ± 8 (6)	92 ± 5 (3)	109 ± 15 (4)	106 ± 5 (5)	103 ± 8 (18)
Mean ± σ	93 ± 13 (96)	86 ± 7 (8)	98 ± 12 (64)	98 ± 11 (80)	96 ± 12 (248)
B. Matrix Spike					
Acrylonitrile-d_3	91 ± 17 (46)		73 ± 23 (44)	100 ± 21 (38)	87 ± 20 (128)
Benzene-d_6	103 ± 13 (46)		109 ± 18 (45)	103 ± 17 (38)	105 ± 16 (129)
Carbon-^{13}C Tetrachloride	91 ± 15 (46)		86 ± 15 (45)	98 ± 15 (38)	91 ± 15 (129)
Chlorobenzene-d_5	100 ± 12 (46)		105 ± 15 (45)	104 ± 7 (38)	103 ± 12 (129)
1,2-Dichloroethane-d_4	97 ± 19 (47)	101 ± 15 (4)	93 ± 16 (42)	104 ± 10 (38)	98 ± 15 (131)
1,1,1-Trichloroethane-d_3	101 ± 20 (45)		86 ± 15 (45)	94 ± 10 (38)	94 ± 15 (128)
1,1-Dichloroethane-2,2,2-d_3	100 ± 12 (46)		90 ± 15 (45)	102 ± 11 (38)	97 ± 13 (129)
1,1,2-Trichloroethane-$^{13}C_2$	102 ± 13 (46)		102 ± 15 (45)	110 ± 9 (38)	104 ± 8 (129)
1,1,2,2-Tetrachloroethane-d_2	105 ± 20 (46)		85 ± 15 (45)	88 ± 9 (38)	93 ± 15 (129)
Chloroform-^{13}C	96 ± 17 (46)		87 ± 15 (45)	95 ± 11 (38)	93 ± 15 (129)
1,1-Dichloroethylene-d_2	91 ± 11 (46)		91 ± 15 (45)	100 ± 9 (38)	94 ± 12 (129)
1,2-Dichloropropane-d_6	104 ± 14 (45)		104 ± 22 (45)	112 ± 9 (38)	106 ± 15 (128)
Ethylbenzene-d_{10}	101 ± 11 (47)	109 ± 17 (4)	101 ± 16 (45)	103 ± 7 (38)	102 ± 12 (134)
Methylene Chloride-d_2	98 ± 12 (46)		102 ± 36 (45)	106 ± 19 (38)	102 ± 22 (129)
Bromoform-^{13}C	91 ± 10 (46)		83 ± 21 (45)	84 ± 11 (38)	86 ± 14 (129)
Toluene-2,3,4,5,6-d_5	100 ± 11 (47)	110 ± 15 (4)	101 ± 14 (45)	105 ± 7 (38)	102 ± 11 (134)
Mean ± σ	98 ± 14(737)	107 ± 16 (12)	90 ± 18(716)	101 ± 11(608)	96 ± 15 (2,073)

σ Standard deviation

(*) Number in parenthesis is the number of data points

TABLE D-2. AVERAGE RELATIVE PERCENT DIFFERENCE FOR DUPLICATE ANALYSIS-WASTEWATER VOLATILE ORGANIC POLLUTANTS

Pollutant	Providence [Mean (*)]	Seattle [Mean (*)]	St. Louis [Mean (*)]	St. Paul [Mean (*)]	Total [Mean (*)]
A. Unspiked Wastewater Duplicates					
Benzene	--	121.0(1)	8.0(1)	--	64.5(2)
Carbon Tetrachloride	0.0(1)	--	--	--	0.0(1)
1,1,1-Trichloroethane	15.8(4)	--	--	28.8(2)	20.1(6)
1,1-Dichloroethane	3.7(2)	0.0(1)	--	47.9(1)	13.8(4)
1,1,2-Trichloroethane	--	18.7(2)	--	--	18.7(2)
1,1,2,2-Tetrachloroethane	--	--	14.6(1)	--	14.6(1)
Chloroform	6.6(4)	3.7(2)	22.7(2)	28.1(3)	14.9(1)
1,1-Dichloroethylene	9.0(3)	--	--	--	9.0(3)
Ethylbenzene	13.8(3)	10.5(1)	4.3(2)	7.8(1)	9.8(7)
Methylene Chloride	14.2(5)	27.9(3)	89.6(4)	47.4(6)	44.4(18)
Bromoform	--	16.7(1)	--	--	16.7(1)
Toluene	33.0(4)	39.4(3)	53.3(3)	14.8(2)	36.6(12)
1,2-Trans-Dichloroethylene	12.0(2)	--	26.8(2)	--	19.4(4)
Tetrachloroethylene	22.7(4)	131.0(2)	14.2(2)	4.7(1)	42.9(9)
Trichloroethylene	16.9(4)	73.5(4)	24.1(2)	26.7(1)	39.7(11)
Vinyl Chloride	27.9(2)	--	--	--	27.9(2)
B. Spiked Wastewater Duplicates					
Acrylonitrile-d_3	10.0 (5)		33.8 (5)	16.5 (6)	19.9 (16)
Benzene-d_6	10.1 (5)		15.5 (5)	2.3 (6)	8.9 (16)
Carbon-^{13}C Tetrachloride	11.9 (5)		10.9 (5)	6.8 (6)	9.7 (16)
Chlorobenzene-d_5	10.0 (5)		5.6 (5)	5.5 (6)	6.9 (16)
1,2-Dichloroethane-d_4	6.7 (5)	Duplicate	12.5 (5)	4.8 (6)	7.8 (16)
1,1,1-Trichloroethane-d_3	6.7 (5)	Spiked	11.2 (5)	5.2 (6)	7.5 (16)
1,1-Dichloroethane-2,2,2-d_3	9.1 (5)	Analysis	11.0 (5)	3.2 (6)	7.5 (16)
1,1,2-Trichloroethane-$^{13}C_2$	8.4 (5)	Not	15.3 (5)	6.2 (6)	9.7 (16)
1,1,2,2-Tetrachloroethane-d_2	8.8 (5)	Performed	4.6 (5)	6.4 (6)	6.6 (16)
Chloroform-^{13}C	7.4 (5)		10.8 (5)	7.3 (6)	8.4 (16)
1,1-Dichloroethylene-d_2	8.1 (5)		11.3 (5)	5.7 (6)	8.2 (16)
1,2-Dichloropropane-d_6	8.8 (5)		5.8 (5)	6.1 (6)	6.9 (16)
Ethylbenzene-d_{10}	12.8 (5)		13.6 (5)	3.9 (6)	9.7 (16)
Methylene Chloride-d_2	6.0 (5)		21.8 (5)	16.1 (6)	14.7 (16)
Bromoform-^{13}C	9.8 (5)		8.8 (5)	7.0 (6)	8.4 (16)
Toluene-2,3,4,5,6-d_5	11.9 (5)		7.9 (5)	5.8 (6)	8.4 (16)

(*) Number in parenthesis is the number of data points

-- Pollutant not detected.

TABLE D-3. PERCENT RECOVERIES - WASTEWATER BASE-NEUTRAL POLLUTANTS

Surrogate	Providence [Mean ± σ (*)]	Seattle [Mean ± σ (*)]	St. Louis [Mean ± σ (*)]	St. Paul [Mean ± σ (*)]	Total [Mean ± σ (*)]
Matrix Spike					
Acenaphthene-d_{10}	82 ± 16 (45)		83 ± 18 (45)	87 ± 9 (34)	84 ± 15 (127)
Bis(2-chloroethyl)Ether-d_4(chloroethyl-1,1,2,2-d_4)	82 ± 35 (38)		91 ± 31 (36)	95 ± 26 (32)	89 ± 31 (106)
1,2-Dichlorobenzene-3,4,5,6-d_4	55 ± 22 (45)		59 ± 24 (44)	64 ± 20 (34)	59 ± 22 (123)
1,4-Dichlorobenzene-2,3,5,6-d_4	52 ± 24 (45)		49 ± 15 (42)	61 ± 18 (34)	53 ± 19 (121)
4-Chlorophenyl Phenyl-d_5 Ether	73 ± 16 (45)		77 ± 16 (47)	83 ± 13 (34)	77 ± 15 (126)
Isophorone-d_8(3-Methyl-d_3-5,5-dimethylcyclohex-2-enone-2,4,4,6,6-d_5)	116 ± 27 (45)		104 ± 41 (44)	107 ± 20 (34)	109 ± 30 (123)
Naphthalene-d_8	84 ± 24 (45)	99 ± 5 (3)	79 ± 21 (45)	86 ± 24 (34)	83 ± 22 (127)
Nitrobenzene-d_5	110 ± 29 (45)	58 ± 47 (3)	96 ± 28 (43)	95 ± 22 (34)	100 ± 27 (125)
N-Nitrosodiphenyl-2,2',4,4',6,6'-d_6-amine	87 ± 21 (45)		81 ± 16 (43)	85 ± 15 (34)	84 ± 18 (122)
Bis(2-ethylhexyl) Phthalate-3,4,5,6-d_4	84 ± 35 (44)		76 ± 25 (42)	95 ± 22 (34)	84 ± 28 (120)
Di-n-butyl Phthalate-3,4,5,6-d_4	79 ± 28 (45)		84 ± 16 (44)	88 ± 15 (34)	83 ± 20 (123)
Di-n-octyl Phthalate-3,4,5,6-d_4	84 ± 31 (44)		76 ± 27 (45)	101 ± 27 (34)	86 ± 28 (123)
Dimethyl Phthalate-3,4,5,6-d_4	27 ± 16 (45)		29 ± 18 (44)	24 ± 9 (34)	27 ± 15 (123)
1,2-Benzanthracene-d_{12}	89 ± 22 (44)		78 ± 29 (45)	100 ± 33 (34)	88 ± 28 (123)
Benzo(a)pyrene-d_{12}	92 ± 51 (43)		69 ± 37 (45)	92 ± 33 (31)	83 ± 41 (119)
Chrysene-d_{12}	89 ± 22 (44)	47 ± 3 (3)	78 ± 29 (45)	100 ± 33 (34)	87 ± 27 (126)
Anthracene-d_{10}	83 ± 17 (45)		89 ± 24 (45)	95 ± 18 (34)	88 ± 27 (126)
Fluorene-d_{10}	86 ± 15 (45)	57 ± 6 (3)	92 ± 18 (45)	104 ± 21 (34)	92 ± 17 (127)
Phenanthrene-d_{10}	83 ± 17 (45)		89 ± 24 (45)	95 ± 18 (34)	88 ± 20 (124)
Pyrene-d_{10}	87 ± 21 (45)		90 ± 26 (45)	102 ± 21 (34)	92 ± 23 (124)
Mean ± σ	79 ± 24(887)	65 ± 15(12)	78 ± 24(879)	88 ± 21(675)	81 ± 23(2,453)

σ Standard deviation

(*) Number in parenthesis is the number of data points

TABLE D-4. AVERAGE RELATIVE PERCENT DIFFERENCES FOR DUPLICATE ANALYSIS - WASTEWATER BASE-NEUTRAL POLLUTANTS

Pollutant	Providence [Mean (*)]	Seattle [Mean (*)]	St. Louis [Mean (*)]	St. Paul [Mean (*)]	Total [Mean (*)]
A. Unspiked Wastewater Duplicates					
Bis(2-ethylhexyl)phthalate	--	133.0(1)	--	17.9(5)	37.1(6)
Di-n-butylphthalate	--	33.0(1)	--	16.2(1)	24.6(2)
Napthalene	--	67.0(1)	--	0.0(1)	33.5(2)
Phenanthrene	--	111.0(1)	--	--	111.0(1)
Di-n-octylphthalate	--	153.0(1)	--	--	153.0(1)
Diethylphthalate	--	--	--	38.8(2)	38.8(2)
B. Spiked Wastewater Duplicates					
Acenaphthene-d_{10}	10.7(5)		14.1(5)	10.6(6)	11.7(16)
Bis(2-chloroethyl)Ether-d_4(chloroethyl-1,1,2,2-d_4)	40.4(5)		71.8(2)	68.7(5)	57.4(12)
1,2-Dichlorobenzene-3,4,5,6-d_4	36.4(5)		38.7(4)	70.9(6)	50.8(15)
1,4-Dichlorobenzene-2,3,5,6-d_4	36.3(5)		38.0(4)	70.9(6)	50.6(15)
4-Chlorophenyl Phenyl-d-$_5$ Ether	15.2(5)		19.2(5)	21.2(6)	18.7(16)
Isophorone-d_8(3-Methyl-d_3-5,5-dimethylcyclohex-2-enone-2,4,4,6,6-d_5)	21.9(5)		36.5(5)	7.4(6)	21.0(16)
Naphthalene-d_8	17.4(5)		32.7(5)	14.5(6)	21.1(16)
Nitrobenzene-d_5	12.0(5)	Duplicate	19.7(5)	14.0(6)	15.2(16)
N-Nitrosodiphenyl-2,2',4,4',6,6'-d_6-amine	19.4(4)		25.4(5)	22.5(6)	22.6(15)
Bis(2-ethylhexyl) Phthalate-3,4,5,6-d_4	28.4(5)	Spiked	46.9(5)	25.5(6)	33.1(16)
Di-n-butyl Phthalate-3,4,5,6-d_4	18.3(4)		16.6(5)	23.7(6)	19.9(15)
Di-n-octyl Phthalate-3,4,5,6-d_4	37.2(5)	Analysis	47.0(5)	20.1(6)	33.9(16)
Dimethyl Phthalate-3,4,5,6-d_4	14.6(4)		41.5(5)	55.6(6)	40.0(15)
1,2-Benzanthracene-d_{12}	20.1(4)	Not	39.7(5)	12.9(6)	23.8(15)
Benzo(a)pyrene-d_{12}	18.0(4)		66.8(5)	47.7(6)	46.1(15)
Chrysene-d_{12}	8.1(5)	Performed	39.9(5)	12.9(6)	19.8(16)
Anthracene-d_{10}	7.0(5)		18.2(5)	16.0(6)	13.9(16)
Fluorene-d_{10}	7.0(5)		10.7(5)	7.0(6)	8.2(16)
Phenanthrene-d_{10}	8.1(4)		18.2(5)	16.0(6)	14.6(15)
Pyrene-d_{10}	25.2(5)		26.3(5)	11.6(6)	20.4(16)

(*) Number in parenthesis is the number of data points

-- Pollutant not detected.

TABLE D-5. PERCENT RECOVERIES - WASTEWATER ACID EXTRACTABLE POLLUTANTS

Surrogate Matrix Spike	Providence Mean ± σ (*)	Seattle Mean ± σ (*)	St. Louis Mean ± σ (*)	St. Paul Mean ± σ (*)	Total Mean ± σ (*)
2,4,6-Trichlorophenol-3,5-d_2	64 ± 18 (45)		65 ± 22 (39)	72 ± 20 (34)	67 ± 20 (118)
4-Chloro-3-methylphenol-2,6-d_2	81 ± 27 (45)		80 ± 28 (39)	80 ± 21 (34)	80 ± 26 (118)
2-Chlorophenol-3,4,5,6-d_4	67 ± 26 (44)		58 ± 27 (38)	72 ± 20 (34)	66 ± 25 (116)
2,4-Dichlorophenol-3,5,6-d^3	63 ± 18 (45)		70 ± 28 (39)	70 ± 22 (34)	67 ± 22 (118)
2,4-Dimethylphenol-3,5,6-d_3	49 ± 25 (45)		69 ± 30 (39)	68 ± 25 (34)	61 ± 27 (118)
2-Nitrophenol-3,4,5,6-d_4	69 ± 21 (45)		69 ± 29 (42)	77 ± 19 (34)	71 ± 23 (121)
2,4-Dinitrophenol-3,5,6-d_3	40 ± 42 (44)		30 ± 36 (38)	14 ± 22 (34)	29 ± 34 (116)
4,6-Dinitro-2-methylphenol-3,5-d_2	49 ± 34 (45)		34 ± 25 (38)	39 ± 22 (34)	41 ± 28 (117)
Pentachlorophenol-13 c_6	81 ± 26 (45)		71 ± 37 (39)	95 ± 41 (34)	82 ± 34 (118)
Phenol-d_6	53 ± 23 (45)	35 ± 3 (3)	39 ± 20 (38)	41 ± 14 (34)	45 ± 19 (120)
Mean ± σ	62 ± 26(448)	35 ± 3 (3)	59 ± 28(389)	63 ± 23(340)	61 ± 26(1,180)

σ Standard deviation

(*) Number in parenthesis is the number of data points

TABLE D-6. AVERAGE RELATIVE PERCENT DIFFERENCES FOR DUPLICATE ANALYSIS - WASTEWATER ACID EXTRACTABLE POLLUTANTS

Pollutant	Providence [Mean (*)]	Seattle [Mean (*)]	St. Louis [Mean (*)]	St. Paul [Mean (*)]	Total [Mean (*)]
A. Unspiked Wastewater Duplicates					
4-Chloro-3-methylphenol	--	7.4(1)	--	12.4(1)	9.9(2)
Phenol	--	25.3(3)	--	--	25.3(3)
2,4-Dimethylphenol	--	--	--	1.7(1)	1.7(1)
B. Spiked Wastewater Duplicates					
2,4,6-Trichlorophenol-3,5-d_2	10.0(5)		14.1(5)	22.4(6)	15.9(16)
4-Chloro-3-methylphenol-2,6-d_2	30.4(5)		20.8(5)	31.4(6)	27.8(16)
2-Chlorophenol-3,4,5,6-d_4	42.5(5)		38.3(3)	40.4(6)	40.7(14)
2,4-Dichlorophenol-3,5,6-d^3	14.3(5)	Duplicate	15.1(5)	25.8(6)	18.9(16)
2,4-Dimethylphenol-3,5,6-d_3	32.8(5)	Spiked	18.3(5)	32.8(6)	28.3(16)
2-Nitrophenol-3,4,5,6-d_4	24.0(5)	Analysis	18.9(5)	29.5(6)	24.5(16)
2,4-Dinitrophenol-3,5,6-d_3	16.5(4)	Not	98.4(3)	69.1(2)	55.5(9)
4,6-Dinitro-2-methylphenol-3,5-d_2	23.8(5)	Performed	77.1(4)	36.2(4)	44.0(13)
Pentachlorophenol-13 c_6	22.2(5)		47.0(5)	31.1(6)	33.5(16)
Phenol-d_6	42.3(5)		23.0(4)	45.0(6)	38.2(15)

(*) Number in parenthesis is the number of data points

-- Pollutant was not detected.

TABLE D-7. PERCENT RECOVERIES - WASTEWATER PRIORITY POLLUTANT METALS

Priority Pollutant	Providence Mean ± σ (*)	Seattle Mean ± σ (*)	St. Louis Mean ± σ (*)	St. Paul Mean ± σ (*)	Total Mean ± σ (*)
A. Method Spike					
Antimony	82 ± 11 (4)	NA	100 ± 0 (1)	82 ± 13 (3)	84 ± 10 (8)
Arsenic	95 ± 6 (4)	NA	86 ± 0 (1)	94 ± 3 (4)	94 ± 4 (9)
Beryllium	93 ± 3 (4)	99 (1)	98 ± 1 (3)	96 ± 1 (4)	96 ± 2 (12)
Cadmium	94 ± 3 (4)	99 (1)	95 ± 8 (3)	95 ± 3 (4)	95 ± 4 (12)
Chromium	93 ± 4 (4)	99 (1)	97 ± 4 (3)	92 ± 1 (4)	94 ± 3 (12)
Copper	95 ± 6 (4)	100 (1)	99 ± 2 (3)	96 ± 2 (4)	97 ± 3 (12)
Lead	96 ± 6 (4)	99 (1)	95 ± 8 (3)	98 ± 6 (4)	97 ± 6 (12)
Mercury	95 ± 4 (4)	NA	100 ± 0 (1)	99 ± 2 (4)	97 ± 2 (9)
Nickel	94 ± 3 (4)	100 (1)	97 ± 5 (3)	97 ± 2 (4)	96 ± 3 (12)
Selenium	91 ± 7 (4)	NA	100 ± 0 (1)	93 ± 1 (4)	93 ± 4 (9)
Silver	91 ± 6 (4)	NA	92 ± 0 (1)	89 ± 7 (4)	90 ± 6 (9)
Thallium	93 ± 2 (4)	NA	93 ± 0 (1)	86 ± 4 (4)	90 ± 3 (12)
Zinc	95 ± 2 (4)	99 (1)	99 ± 1 (3)	97 ± 3 (4)	97 ± 2 (12)
Mean ± σ	93 ± 5 (52)	99 ± 1(7)	97 ± 3 (27)	92 ± 4 (51)	94 ± 4(137)
B. Matrix Spike					
Antimony	121 ± 20 (3)	84 (1)	95 ± 21 (3)	132 ± 0 (1)	108 ± 15 (8)
Arsenic	115 ± 23 (3)	103 (1)	102 ± 4 (3)	120 ± 7 (3)	111 ± 10 (10)
Beryllium	83 ± 6 (3)	109 (1)	105 ± 7 (2)	87 ± 6 (3)	92 ± 6 (9)
Cadmium	91 ± 4 (3)	107 (1)	98 ± 11 (3)	91 ± 2 (3)	95 ± 5 (10)
Chromium	93 ± 4 (3)	112 (1)	102 ± 7 (3)	91 ± 0 (1)	99 ± 4 (8)
Copper	85 ± 16 (3)	92 (1)	98 ± 2 (2)	86 ± 8 (3)	89 ± 8 (9)
Lead	79 ± 0 (1)	106 (1)	100 ± 9 (3)	98 ± 0 (2)	97 ± 4 (7)
Mercury	90 ± 0 (1)	NA	95 ± 12 (3)	110 ± 0 (1)	97 ± 7 (5)
Nickel	88 ± 0 (1)	103 (1)	97 ± 8 (3)	NA	96 ± 5 (5)
Selenium	91 ± 24 (3)	94 (1)	97 ± 16 (3)	111 ± 9 (3)	99 ± 15 (10)
Silver	NA	99 (1)	79 ± 27 (2)	NA	86 ± 18 (3)
Thallium	NA	79 (1)	75 ± 18 (2)	NA	76 ± 12 (3)
Zinc	85 ± 6 (3)	100 (1)	104 ± 2 (2)	88 ± 3 (3)	92 ± 3 (9)
Mean ± σ	94 ± 11 (27)	99 ± 10(12)	96 ± 11 (34)	99 ± 5 (23)	97 ± 8 (96)

σ Standard deviation
(*) Number in parenthesis is the number of data points
NA Not available

TABLE D-8. AVERAGE RELATIVE PERCENT DIFFERENCES FOR DUPLICATE ANALYSIS-WASTEWATER PRIORITY POLLUTANT METALS

Priority Pollutant	Providence Mean (*)	Seattle Mean (*)	St. Louis Mean (*)	St. Paul Mean (*)	Total Mean (*)
A. Wastewater Duplicates					
Antimony	0.0 (5)	0.0 (1)	0.0 (2)	0.0 (2)	0 (10)
Arsenic	0.0 (5)	18.1 (1)	10.3 (2)	0.0 (2)	3.9 (10)
Beryllium	0.0 (6)	0.0 (1)	0.0 (3)	6.0 (3)	1.4 (13)
Cadmium	11.1 (6)	18.1 (1)	14.4 (3)	4.4 (3)	7.1 (13)
Chromium	6.1 (6)	3.6 (1)	33.7 (3)	1.5 (3)	11.2 (13)
Copper	4.3 (6)	4.4 (1)	23.1 (3)	5.5 (3)	8.9 (13)
Lead	6.4 (6)	0.0 (1)	3.7 (3)	9.3 (3)	6.0 (13)
Mercury	0.0 (4)		0.0 (2)	0.0 (2)	0.0 (8)
Nickel	4.2 (6)	6.8 (1)	4.1 (3)	0.0 (3)	3.4 (13)
Selenium	0.0 (5)	0.0 (1)	0.0 (2)	0.0 (2)	0.0 (10)
Silver	108.0 (2)	18.1 (1)	0.0 (2)	46.1 (2)	46.6 (7)
Thallium	40.4 (2)	0.0 (1)	0.0 (2)	1.9 (2)	12.1 (7)
Zinc	2.8 (6)	3.8 (1)	24.9 (3)	8.7 (2)	9.4 (12)

B. Spiked Duplicates - Not Applicable

(*) Number in parenthesis is the number of data points